# THE CLIMATE CRISIS: NATIONAL SECURITY, PUBLIC HEALTH, AND ECONOMIC THREATS

## HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

OF THE

## COMMITTEE ON ENERGY AND COMMERCE

## HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

FEBRUARY 12, 2009

**Serial No. 111–3**

Printed for the use of the Committee on Energy and Commerce
*energycommerce.house.gov*

U.S. GOVERNMENT PRINTING OFFICE

63–825 PDF WASHINGTON : 2011

For sale by the Superintendent of Documents, U.S. Government Printing Office
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SUBMITTED MATERIAL



[1] Mr. Schrag did not respond to submitted questions for the record.
[2] General Sullivan did not respond to submitted questions for the record.

# THE CLIMATE CRISIS: NATIONAL SECURITY, PUBLIC HEALTH, AND ECONOMIC THREATS

**THURSDAY, FEBRUARY 12, 2009**

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT,
COMMITTEE ON ENERGY AND COMMERCE,
*Washington, DC.*

The subcommittee met, pursuant to call, at 10:05 a.m., in room 2123 of the Rayburn House Office Building, Hon. Edward Markey (chairman) presiding.

Members present: Representatives Markey, Doyle, Inslee, Butterfield, Melancon, Matsui, McNerney, Welch, Dingell, Boucher, Pallone, Engel, Green, Capps, Harman, Gonzalez, Baldwin, Matheson, Barrow, Waxman (ex officio), Upton, Hall, Stearns, Whitfield, Shimkus, Pitts, Burgess, Scalise, and Barton (ex officio).

Also present: Representative Christensen.

Staff present: Dave Rapallo, Melissa Bez, Joel Beauvais, Alexandra Teitz, Matt Weiner, Caren Auchman, Jeff Baran, Amanda Mertens Campbell, Andrea Spring, Peter Spencer, and Garrett Golding.

## OPENING STATEMENT OF HON. EDWARD J. MARKEY, A REPRESENTATIVE IN CONGRESS FROM THE COMMONWEALTH OF MASSACHUSETTS

Mr. MARKEY. Good morning, and welcome to the Subcommittee on Energy and Environment and this very important opening hearing.

We stand at a critical moment in history. The country is facing some of the deepest, most complex challenges it has ever confronted: an economy in peril, a broken energy system, a climate in crisis. These problems are inseparable and so are the solutions. We now have a choice to make. We can continue to sit on our hands, allowing our children and grandchildren to inherit a planetary catastrophe, or we can take action to unleash a technology revolution that will revive our economy while protecting our national and environmental security.

Today's hearing is the first of many the subcommittee will hold in the coming weeks as we work with Chairman Waxman and Ranking Members Barton and Upton to pass a comprehensive climate and energy piece of legislation out of committee by Memorial Day. We begin this process by hearing from a distinguished panel about the grave threats that global warming poses to national and global security, public health, and economic growth. These witnesses are here in part to purge whatever complacency remains

after 8 years of climate policy founded on denial, obfuscation, and delay. The American people are ready for bold action, and they expect Congress to pass legislation that will create jobs, save consumers money, and protect the planet. There is now a robust scientific consensus that global warming is happening, that manmade greenhouse gas emissions are largely responsible, and that if we fail to dramatically reduce those emissions starting now, catastrophic impacts will result.

This leads to the real question in this debate: Can we afford not to act? The human and economic costs of continued delay are staggering, whether it is villages falling into the sea in Alaska, flooding in the Midwest, droughts becoming harder, longer, and more frequent in the south, or crop failure and water scarcity feeding a genocide in Sudan. We know that changes brought on or exacerbated by human-induced climate change are happening. These impacts will threaten national and global security, endanger public health, and damage the American economy.

In last year's National Intelligence Assessment, the heart of our national security establishment, called the climate crisis a threat to American security. Public health professionals have told us that global warming is already causing tens of thousands of deaths annually in the developing world and poses a serious threat to public health here at home.

Our economy is also in grave danger. If left unchecked, global warming will cost the United States trillions of dollars in coming years. Recent studies suggest that by 2050, our Nation could face at least half-a-trillion dollars in damages every year due to climate change, a 1.5 percent cut in GDP. Global GDP could fall as much as 20 percent.

The costs of inaction are not limited to the impacts of global warming. They also include the price of lost opportunity. America was once the world's leader in renewable energy technologies but we are now losing those jobs to our overseas competitors. If we are laggards instead of leaders in the fight against global warming, we will miss out on the greatest economic opportunity of our time. Three point six million Americans have lost their jobs since the beginning of the current recession and climate legislation offers them new hope.

In less than 300 days, the attention of the world will turn to Copenhagen, site of the negotiations that we hope will produce a plan forward for the global community to address climate change. The House of Representatives is now taking its first steps down the path towards a responsible policy on climate. As we put our domestic house in order, we can return the United States to its rightful place of leadership in solving the most pressing problems facing the world.

That completes the opening statement of the Chair.

Mr. MARKEY. We now turn and recognize the ranking member of the subcommittee, the gentleman from Michigan, Mr. Upton.

**OPENING STATEMENT OF HON. FRED UPTON, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MICHIGAN**

Mr. UPTON. Well, thank you, Mr. Chairman.

Today's hearing does touch on a number of important aspects of the climate change debate, and I have said at nearly every climate change hearing that for me, I don't dispute the science. Right or wrong, the debate over the modeling and science appears to be over. We have got to get past that and look at our policy options and consequences of the actions that we need to take to address that issue. Whatever policy we deploy has to have real environmental impact, meaning a tangible change in global temperature, not just arbitrary reductions in $CO_2$ emissions. I want to know if the United States cuts emissions and China does not, how much will that impact global temperatures? With the ever-increasing emissions of the developing world, even if the United States reduces its emissions to zero, there would be no change in global temperature. Our climate change policies must be linked to a realistic reduction in those temperatures. Cap-and-trade legislation that we have seen so far, specifically legislation that was voted down in the Senate last year, and legislation introduced last Congress by the full committee chair would create economic opportunities for China and India, and it would also create a national security threat, I think, for this country.

There is an analysis that is going to be released in the coming weeks by the National Commission on Energy Policy. It should be noted that the head of that group was also a top energy and climate advisor to President Obama during his campaign. They found that many energy-intensive businesses would fall far below a financial tipping point if Congress were to pass climate legislation similar to the bill that failed in the Senate last year. These companies would go offshore, creating economic opportunities for China and India, while making the environment, not to mention our economy, worse. Furthermore, if we lost those key industries and their many jobs, I think we would be on a weaker national security footing.

History has shown that the United States is stronger with a robust manufacturing and industrial base. The jobs and industries that will bear the greatest cost of climate legislation are the very same industries that we need to keep in America to remain a power on the world stage. What happens to our national security when we don't manufacture much? What happens when we order all the steel and aluminum from China? If we take the wrong legislative path dealing with climate change, we run the real risk of permanently destroying our manufacturing and defense supply chains. I find it ironic that while the big issue of today is a stimulus package to revive our economy, we are also getting ready to go down a legislative path that, by all accounts, will reduce GDP, send jobs overseas, and make energy more expensive. Let us be honest. By design, that is how cap-and-trade works.

Just last year, Members of this Congress were proposing legislation that would include residential electricity prices by 28 percent by the year 2015, over 40 percent by the year 2020, reduce our GDP in 2015 by 2.3 percent, or $402 billion, and by 2050 by a 6 percent figure with a dollar amount a staggering $3 trillion. Michigan already is one of the hardest hit states in our weak economy. We would be disproportionately impacted. NAM did a detailed analysis of the impact on my home State of Michigan and the impact on jobs. The primary cause of job losses in Michigan would be

the lower industrial output due to higher energy prices, the high cost of compliance, and greater competition from overseas manufacturers with lower energy costs. Most energy prices would rise under the proposals, particularly for coal and oil and natural gas. If we end up with legislation that looks like anything that we saw last year, doing an $800 billion stimulus this week won't be enough. We are going to send 3 million jobs overseas in the next 6 years and raise nearly $2,000 per household in additional costs. That stimulus package isn't going to be nearly enough to soften the blow.

I do believe that we have to do work to address climate change. I don't dispute the science. But our response must be to protect the economy. It has got to be tied to international action and it must have a tangible environmental benefit. Most importantly, I think we need to focus on all of the above. That includes conservation, that includes renewable resources and yes, that includes nuclear, which has, as we know, no emissions of $CO_2$. That is what we need to do to create jobs and, I think, to have a measured impact on improving our economy and doing it in the right, smart way, and I yield back my time.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the chairman of the full committee, the gentleman from California, Mr. Waxman.

**OPENING STATEMENT OF HON. HENRY A. WAXMAN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA**

Mr. WAXMAN. Thank you very much, Mr. Chairman, for recognizing me and for holding this hearing.

As the Energy and Commerce Committee develops legislation to reduce greenhouse gas emissions, we are going to spend a considerable amount of time examining the potential costs of different approaches. We will have detailed government analysis and other assessments to project the possible effects of various proposals on electricity rates, gas prices, economic growth, and a host of other indicators, but what I hope we will not do is have an analysis of all of this compared to the analysis that we will hear about today if we do nothing. We are going to consider a different set of costs if we do nothing, the impact of these costs on our national security, public health, and the global economy.

With global warming comes rising sea levels, severe droughts, increasingly intense storms, and more-frequent fires and the loss of agricultural land. These effects harm people and they impose huge costs on the economy. Human health will also suffer, even if we make significant improvements to our public health systems. For example, as heat waves increase in frequency and severity, more people will get sick, more people will die from heat-related illnesses, and as we saw with Hurricane Katrina, extreme weather events are harder on the sick than on the healthy and they cause additional health problems. With these and many other effects of global warming, the most vulnerable among us will be the hardest hit and this alone is a reason to act.

But when military experts examine global warming, they see additional costs that also demand action. In 2007, a board of 11 re-

tired admirals and general reviewed the risks from climate change around the globe. Some of these retired military officials had not viewed climate change as a threat prior to this review, but based on their review, the entire board came to this conclusion: Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world. They warned of large populations moving in search of resources and weakened and failing governments, which would foster conditions for internal conflicts, extremism and movement toward increased authoritarianism and radical ideologies. Retired General Anthony Zinni, former commander-in-chief of the U.S. Central Command, put it this way: "We will pay for climate change one way or another. We will pay to reduce greenhouse gas emissions today or we will pay the price later in military terms, and that will involve human lives. There will be a human toll. There is no way out of this that does not have real costs attached to it. That has to hit home."

I look forward to exploring these issues further with today's witnesses. I also look forward to working with you, Mr. Chairman, and all the members of our committee as we develop legislation over the coming months. Doing nothing is not an option that anybody should look at without feeling a sense of alarm.

I yield back my time.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Florida for 2 minutes, Mr. Stearns.

**OPENING STATEMENT OF HON. CLIFF STEARNS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF FLORIDA**

Mr. STEARNS. Thank you, Mr. Chairman.

In light of the dire warnings that you have outlined, you know, I really think what we need to do is innovate rather than regulate our way out of this energy dilemma. At a time when we are trying to stimulate our economy and avoid entering what we think is a prolonged recession, possibly a depression, there is all this talk about, Mr. Chairman, you bringing an energy bill here before Memorial Day, and I assume this energy bill would be patterned after the Lieberman-Warner bill, which would include cap-and-trade and a lot of the other highly regulatory measures. So I want us to be careful here in light of the economy that we don't want to destroy American jobs.

As pointed out by the ranking member from Michigan, China has already surpassed the United States as the leading greenhouse gas emitter and India is not far behind. With equivalent efforts to limit these gases among China and India alone, the United States stands to lose many hundreds of thousands of jobs to these countries, which will profit from unilateral action taken by the United States. If we simply go ahead and do this without a cooperative effort with India and China, we will be hurting our workers today.

Now, according to one leading think tank, if legislation similar to the Lieberman-Warner bill is enacted, they are talking about annual job losses that would exceed 500,000 before 2030 and could approach 1 million jobs lost. In my home State of Florida alone, we are projected to lose about 300,000 jobs by the year 2030 if this similar type of Lieberman-Warner bill is passed before this committee.

Aside from losing these very desperately needed jobs to other countries, American families obviously would suffer under a cap-and-trade system. Now, the Charles River Associates International, its headquarters in Boston, Massachusetts, the chairman's hometown, stated that if we implemented that type of bill, the number of people that would go on unemployment would increase, subsequently into some type of welfare, and they project losses of $4 to $6 trillion, so I think we have to be cautious, Mr. Chairman, and I need to again say we need to innovate rather than regulate. Thank you.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the chairman emeritus of the committee, the gentleman from Michigan, for 5 minutes.

**OPENING STATEMENT OF HON. JOHN D. DINGELL, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MICHIGAN**

Mr. DINGELL. Mr. Chairman, I thank you for your courtesy and I thank you for holding this hearing today.

As I said at the last climate change hearing held by the full committee, global climate change is the most serious environmental issue confronting this Nation. What we will hear today and what we heard in the subcommittee hearing last summer, however, is that this issue is not just an environmental matter. Instead, it poses a major threat to our national security and to the public health as well.

We often hear about the costs of addressing climate change, and to be very clear, there will be significant monetary costs. Anybody who thinks otherwise is fooling themselves. But we must also make it clear that there is great cost to inaction. That we understand both the cost of action and the cost of inaction is of the utmost importance in designing fair and balanced climate change legislation.

Now, I will not pretend that this is going to be an easy task nor can I assure you that it will not be. To start with, putting a dollar value on inflation is difficult. How do you value the effect of the storms that might happen or the value of potential species extinction? This is not easy to say as to how we should act. On the contrary, the scientific evidence is in and it is clear: We have no choice but to act. That is why I, along with Representative Boucher, released a draft last year of a bill to address climate change. It was an interesting piece of work, and interestingly enough, it embodied provisions which were supported by all parts of those involved in the controversy by the environmentalists and by business and industry, and it was a document which I think would be fairly easy for everyone to come to some kind of agreement on.

Our witnesses today will tell us that our failure to act could put the planet and the country at risk or even risk of graver and greater consequences. Today's hearing will help us to understand potential security and the costs of those consequences. I hope as we go about the consideration of these questions we will take a look at the draft that Mr. Boucher and I released last year and that this will be one of the documents which we will consider as we go about the business of drafting legislation on this very important question.

Thank you, Mr. Chairman.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Kentucky, Mr. Whitfield.

**OPENING STATEMENT OF HON. ED WHITFIELD, A REPRESENTATIVE IN CONGRESS FROM THE COMMONWEALTH OF KENTUCKY**

Mr. WHITFIELD. Thank you very much, Mr. Chairman, and we appreciate this hearing today.

Kevin Trenberth, who was one of the lead authors of the United Nations' 2007 Intergovernmental Panel on Climate Change, stated in a blog that he has on Nature's journal that in fact there are no predictions by the Intergovernmental Panel on Climate Change and there never have been. The science is not done because we do not have reliable or reasonable predictions of climate. And so when we talk about the cost of not acting, I think it is particularly speculative. But when we talk about the cost of acting, there certainly is more reliable evidence of exactly the cost of acting, particularly when you are talking about implementing a cap-and-trade system. We can easily go to Europe and determine the cost of acting in Europe. We know that emissions have actually increased since the cap-and-trade system was implemented in Europe. We also know that there have been significant job losses, and we also know that using a model based on the Lieberman-Warner bill, as my friend from Florida stated, the prediction is that throughout the United States by the year 2030 there would be 1 million people without jobs, primarily because the job loss would be caused by lower industrial output because of higher energy costs. And when you have countries like China, India and others that are relying more and more on coal production because of the low cost of coal, America is going to become even less competitive.

And so as we talk today about impact on national security, the economy, and public health, I hope that we have some very strong scientific and economic evidence of the cost of inaction. I don't have any time left.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Pennsylvania, Mr. Doyle.

**OPENING STATEMENT OF HON. MICHAEL F. DOYLE, A REPRESENTATIVE IN CONGRESS FROM THE COMMONWEALTH OF PENNSYLVANIA**

Mr. DOYLE. Thank you, Mr. Chairman. I want to start my remarks by thanking you for having this important hearing today.

Mr. Chairman, at a time when our Nation is facing the worst economic crisis in generations, hearings like this one are very important. We must fully understand not only the cost we incur as we attempt to stimulate our economy today but what costs our Nation will face if we do not use this opportunity to address climate change as we rebuild our economy.

As I have said before, the question of whether climate change is happening and if the actions of mankind are having an effect on its progression is over. While there are a few scientists out there that still cast doubt, it can be said that the overwhelming opinion in the scientific community is that this crisis is very real, mankind is in part responsible, and there are actions we can take now to

slow and reverse this very dangerous trend. However, this hearing is not about if climate change is real, this hearing is about the cost of action and the cost of inaction.

As many of our witnesses will also testify to, I believe that doing nothing is no longer an option as there are very real costs that will happen if the United States continues to lag behind other nations as they move forward to address this truly global problem. President Obama stated earlier this week that the country that figures out how to make cheaper energy that is also clean will win the economic competition in the future. Regardless of how any member of this committee feels regarding the science of global warming, I would hope that every member here would agree with the President's statement. I don't care if you are joining the climate discussion because you feel there is a profound environmental threat or if you are joining the climate discussion because you see economic advantages for the United States, it is critical that we all work to ensure that we position our nation to be the world's leader in the production of cheap and clean energy.

Like the dot-com boom of the 1990s, the energy revolution will provide jobs, the trade, and economic growth that our citizens deeply desire. It is critical that this committee act this year and put our Nation back on a path for the production, distribution, and sale of not only cheap energy, but all the technology that will be required to produce it.

With that, I yield back, Mr. Chairman.

Mr. MARKEY. I thank the gentleman. The chair recognizes the gentleman from Illinois, Mr. Shimkus.

Mr. SHIMKUS. Thank you, Mr. Chairman. Ryan, just put this up. [Slide shown.]

This is a Peabody Mine #10 in Kincaid, Illinois, prior to the Clean Air Act. It was an efficient operation with a power plant just across the street. These are the workers who were employed at this mine. They are the faces of the middle class. They are the faces of the United Mine Workers. They are the faces of the unemployed.

I attended a rally at the Christian County Fairgrounds, which attacked the company for their closure of this mine. The real culprit was legislation passed by this government in the Clean Air Act. I will fight to keep this from happening to my mineworkers again, and I yield back my time.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Texas, Mr. Gonzalez.

Mr. GONZALEZ. I will waive.

Mr. MARKEY. The chair recognizes the gentleman from Utah, Mr. Matheson.

Mr. MATHESON. I will waive.

Mr. MARKEY. The chair recognizes the gentleman from North Carolina, Mr. Butterfield.

**OPENING STATEMENT OF HON. G.K. BUTTERFIELD, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NORTH CAROLINA**

Mr. BUTTERFIELD. Thank you very much, Mr. Chairman, for convening this hearing, and thank you for your leadership, not only on this committee, but on this very issue that we are talking about.

You have been talking about it for so long, long before I came to this Congress, and I just thank you so much.

As with most disasters, Mr. Chairman, the effects of climate change will be most significantly experienced by low-income people both in our country and abroad. Any climate effect that strains essential resources, such as water, food, and shelter is multiplied on poor people who already live on tight margins. For this and other reasons, the cost of inaction on climate change rises exponentially for the poor of this country, as well as those living in developing regions around the world. James Lyons testified before the subcommittee last year that people living in developing countries are 20 times more likely to be affected by climate change disasters. Drought, disease, and severe weather events are typically exacerbated in these developing areas, as compared to more-developed regions.

The consequences of domestic climate change for the poor could include chronic illnesses and the loss of property, yes, the loss of property and livelihood. As temperatures rise, air quality drops and asthma cases rise. Numerous studies have shown a clear link between poverty and increased susceptibility to asthma, and people of color are three times likelier to suffer from asthma-related conditions. Much of my district in North Carolina includes low-lying and coastal lands. A recent University of Maryland study projected an 18-inch rise in sea level by 2080, which would cause over $2.8 billion in property losses in just four of my counties. Bertie County, one of my poorest counties, would lose an estimated $9 million in property. That does not sound like a lot to my friends from urban areas but it is indeed in a rural area. Inaction would affect their homes, their businesses, and the lives that they have built with their families.We must act in this Congress, but as we push forward in developing policy that would set scientifically-based targets for greenhouse gas reductions, we must be sure to remember the needs of low-income people both here in this country and around the world.

Thank you, Mr. Chairman. I yield back.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Louisiana, Mr. Scalise.

**OPENING STATEMENT OF HON. STEVE SCALISE, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF LOUISIANA**

Mr. SCALISE. Thank you, Mr. Chairman. I appreciate the opportunity to discuss the effects of sweeping climate change legislation. I certainly look forward to hearing the testimony from our panel today.

I would note that for thousands of years, climate and temperature cycles of the Earth have been in effect, and this Congress must not hastily pass sweeping climate change legislation without regard to its negative economic impact. At a time when our economy is struggling and when we must make bold efforts to become energy independent for national security and other reasons, it is our job to carefully weigh the costs and benefits of each proposal we will face before this subcommittee. I remain concerned that we have focused too little on the effect of sweeping climate change and

what it would have on our economy as well as the historical record throughout our history.

As Congress considers radical policy changes here in Washington, we are already seeing some of the negative effects take place by decisions that private firms are making today. There is a major steel manufacturing plant in this country that is currently making a decision between building a $2 billion plant. Right now their choices are between Louisiana, near my district, or Brazil. What they have said, according to the CEO of the company, imminent U.S. policy changes dealing with climate change are negatively affecting their decision to build a major plant here in the United States, which would create 700 good jobs. Those are 700 jobs that because of the decisions that are being discussed here, if we make negative policy changes that are radical, they would run those 700 jobs out of this country and send them to Brazil.

Becoming more energy efficient is a good thing, but I urge caution in proceeding in a radical fashion that could produce dire consequences to our economy without yielding any benefits to our environment.

Thank you, and I look forward to hearing from our panel.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentlelady from California, Ms. Harman.

**OPENING STATEMENT OF HON. JANE HARMAN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA**

Ms. HARMAN. Thank you, Mr. Chairman, and my thanks to you and also to the chairman of the full committee, Mr. Waxman, for your work on the stimulus package that we will vote on tomorrow. There are sections in it on health and energy that are absolutely critical and that obviously owe a lot to the work of this committee. I just want to say as a Californian how much I appreciate the effort to increase the share of FMAP payments that will go to counties and cities.

Mr. Chairman, to paraphrase our new President, leaders must be able to do more than one thing at a time. That means fixing the economy and beginning to solve, perhaps, the most pressing public policy challenge of this generation, global climate change. I recognize, and we have just heard it, and that there are a few on this committee who still doubt the science of climate change and its implications, but I am not one of them. The climate is changing more radically and more quickly than we once believed and the consequences of inaction will be catastrophic.

I want to acknowledge the work of some of the witnesses before us. A few years back, Jim Woolsey helped to arrange a simulation in my congressional district called Oil Shock Wave. I think he played the President, and I was Secretary of Defense and former California Governor Pete Wilson was Secretary of State, and whatever firepower we brought to that, we couldn't solve the implications of shockingly high oil prices on the U.S. economy, and we have actually now a few months back seen what happens with that. So I want to thank him for his work on that, and as you will hear in a minute, his work on the implications on the electric grid and other things of some of these issues.

And as for General Sullivan, you will remember that we had a big fight in Congress adding a section to the intelligence authorization bill a few years ago to require a national intelligence estimate on the effects of climate change on our national security. Many people laughed about that. Well, I don't think it is a laughing matter, and I think we have learned that famine and drought produce the perfect conditions for recruiting terrorists, and I worry about that a lot.

So let me just close by saying if we worry about jobs, let us get this right and build the jobs of the future and keep America secure. Thank you, Mr. Chairman.

Mr. MARKEY. The gentlelady's time has expired. The chair recognizes the ranking member of the full committee, the gentleman from Texas, for 5 minutes.

**OPENING STATEMENT OF HON. JOE BARTON, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TEXAS**

Mr. BARTON. Thank you, Mr. Chairman. It is good to finally engage in the debate. Global warming or climate change is certainly an issue that we have walked around the edges of in this Congress for the last several sessions, and I think it is an important issue and I think it is good to have these witnesses and the ones that are going to appear after them to begin the information-gathering process.

I am, I don't think it is a surprise, a skeptic that mankind is causing the climate to change. I do agree that the climate is changing. That is self-evident. I just have a problem because I am a registered professional engineer. When I look at all the evidence of the past climate change cycles to see what is different about this one, that somehow mankind is the cause, the supposed expert IPCC models, unless they miraculously improved them in the past 3 to 4 months, don't do a very good job of even predicting the past. Half the time they get the degree of change and the direction wrong. Now, maybe they have changed some in the last 6 months and maybe some of these witnesses can educate me on that.

We understand that global warming is a theory and it may even be a practical theory, but I am not yet ready to accept that it is a theology. Some of the more fervent global warming advocates do take it as a theology or a pseudoreligion. When you try to debate with them the facts of the case, they get very intensely upset.

Global warming advocates believe that humanity's $CO_2$ emissions harm the earth by raising the global temperature, and they say that only draconian action led by the United States will save the planet. The U.S. cap-and-trade group that testified at the full committee several weeks ago supports a proposal that would cut $CO_2$ emissions by 80 percent in the United States by the year 2050. Again, I can stand to be corrected ,but my understanding, if we cut our $CO_2$ emissions by 80 percent, we are back to levels that we last experienced in the United States around World War I, when we had about 120 million people in this country and over half of those lived on farms, and the per capita income was in the hundreds of dollars per person instead of the tens of thousand of dollars per person that it is today.

If we do what the advocates say we should do, the econometric models, which I believe are more accurate, almost guarantee a 2 to 3 percent GDP negative growth, in other words, a contraction of GDP on an annual basis. You want to talk about launching another Great Depression; let us do some of the things that require that kind of a contraction.

Instead of heading back to the Bronze Age, I think we should look to the future for solutions. I think it is possible on a bipartisan basis to do things that actually further the science, further the research into carbon capture and conversion, accelerate the use of existing technologies like nuclear power, some of the alternative energy sources that we know are zero emissions, wind power, new hydropower, things like that. We can have a bipartisan solution, a bipartisan proposal on those kinds of things.

No poor country values its environment more than it values its people's ability to make a living. One of the problems we are going to have, it is one thing to ask an industrialized society to do with a little bit less, but it is another thing entirely to ask an evolving society to not do at all. If you go to some of the countries in Africa and Asia, some of the former European Soviet Union satellites in eastern Europe and ask them to just not have what we have taken for granted in this country for the last 50 years, I think we are going to get a rude awakening. They are just not going to do it. If the choice is wash your clothes in the ditch or put electricity that is generated by a coal-fired power plant so that you can actually buy a washing machine, most people are going to build a coal-fired power plant.

So again, that is why we need to do things like Mr. Boucher's bill on $CO_2$ research for conversion and capture and do some of the things that I have already alluded to.

I see that my time is about to—in fact, it has expired, Mr. Chairman. I appreciate you giving me that notice. Suffice it to say that I am very involved in this debate. I appreciate the process where we do the hearings before we move a bill. That is somewhat unique in this Congress, and I appreciate you doing that. I look forward to the debate.

Mr. MARKEY. I thank the gentleman very much. The chair recognizes the gentlelady from California, Ms. Matsui.

**OPENING STATEMENT OF HON. DORIS O. MATSUI, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA**

Ms. MATSUI. Thank you, Mr. Chairman, for calling today's hearing. I applaud your leadership and vision on this critical and pressing issue. I look forward to working with you and with all the members on the committee to craft responsible solutions to the problem of climate change. I would also like to thank today's panelists for sharing their expertise with us.

Climate change is a problem that demands action and demands action now. My hometown of Sacramento is a perfect illustration of why we need to solve climate change as soon as possible. In Sacramento we live at the confluence of two great rivers. We also live at the foot of the Sierra Nevada Mountain range. We have learned to manage the winter rains that test our levies and we learned to

manage the spring snowmelt that flows down from the Sierras each year. But global warming threatens to upset this finely-tuned balance. This year we are having a major drought. In recent years, extreme amounts of rain have strained our infrastructure. Behind these changing climatic patterns is a constant threat of flooding. Protecting my hometown from flooding is my top priority. This makes addressing climate change that much more urgent for me. Nearly half a million people, 110,000 structures, the capital of the State of California and up to $58 billion are at risk from flooding in Sacramento.

Unless we take action now, our way of life in Sacramento and California and across the country will be changed forever. I look forward to hearing from each of today's witness of how we can advance solutions to global warming that keep people safe and help us avoid disaster here at home.

Thank you again for your leadership on this issue, Mr. Chairman, and with that I yield back the balance of my time.

Mr. MARKEY. The gentlelady's time has expired. The chair recognizes the gentleman from Texas, Mr. Burgess.

**OPENING STATEMENT OF HON. MICHAEL C. BURGESS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF TEXAS**

Mr. BURGESS. Thank you, Mr. Chairman. I appreciate you holding the hearing today titled "The Climate Crisis: National Security, Public Health, and Economic Threats." In fact, the title kind of evokes what columnist George Will spoke about last Sunday: The only thing we have to fear is insufficiency of fear.

If I were to list the top 100 national security threats facing our country today and rank them from one to 100, I would be hard pressed to put climate change in the top tier, the top 50, or perhaps even in the top 75. Now, there may be a national security threat but so are birds flying about the Hudson River. Scaring people into feeling better about paying more for their energy consumption under the guise of potential greater national security is a hard sell. People in my district know that as a Nation we have got greater domestic security concerns and, especially now, greater economic concerns to address before we try to tackle the weather and beach erosion.

We simply do not know the future or what technology may exist in the future but we do know that the technology that we will need to dramatically change the way we deliver and consume energy will require a strong and growing economy. Strong and growing economies have obligations to protect their national security. I would also argue that the needs of challenged societies do not hinge on the exploitation of natural resources, but rather on the lack of affordable resources, given the needs of their people. Strong and growing economies have the financial resources to provide additional aid to people in need. Strong and growing economies can protect themselves more easily and adapt to changes and mitigate the effects of natural disasters. Let us ensure that our ability and the ability of developing economies to prosper are not put at future risk by the way we choose to address the issue of human contributions to what we now know as climate change.

I thank you for the consideration, Mr. Chairman. I will yield back the balance of my time.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Washington State, Mr. Inslee, for an opening statement.

**OPENING STATEMENT OF HON. JAY INSLEE, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF WASHINGTON**

Mr. INSLEE. Thank you, Mr. Chairman.

I would like to make two points. First, in response to Mr. Barton's entreaty that we follow science rather than theology, I think all of us have to be willing to accept new science, and I want to say that I have been wrong on this issue of global warming now for several years. I have been advocating action for this and I have been wrong. I based my earlier positions on this climate change report of 2007, the physical science basis consensus product of a couple thousand of the world's best scientists including, I believe Nobel Prize winner Dr. Chu, the film, "An Inconvenient Truth" and a lot of other things I have read. All of those things were wrong. They grossly understated the threat that we are facing today. Because during the last 12 months we have had an avalanche of information scientifically to indicate our previous projections grossly understated the pace and depth and scope of this threat.

While we previously thought the Arctic would be around in 50 years, it is gone now virtually in the summer. While we previously said that glaciers in Glacier National Park would be around in decades, they are essentially going much more rapidly. While we previously thought ocean acidification would take 70 years to make it impossible for coral reefs to exist, they are now rapidly approaching that level right now off the coast of the State of Washington.

This is a much deeper problem than we thought it was 12 months ago and that is why it demands urgent action, and it demands action tomorrow, when we vote on the economic recovery bill, which is the largest investment in innovation, creativity, and job creation in green-collar jobs in American history, $90 billion to do exactly what my Republican friends say they believe in, which is innovation, and I entreat them to vote for the largest investment in innovation at A123 Battery Company with lithium ion batteries, at the Ostra solar-concentrated solar thermal plant, at Magna Drive in Bellevue, Washington, at Detroit's GM, where we want to make electric cars. I hope they will vote with us tomorrow to innovate our way out of this problem. Thank you.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Pennsylvania, Mr. Pitts.

**OPENING STATEMENT OF HON. JOSEPH R. PITTS, A REPRESENTATIVE IN CONGRESS FROM THE COMMONWEALTH OF PENNSYLVANIA**

Mr. PITTS. Thank you, Mr. Chairman, for holding this hearing. I believe that it is of the utmost importance to protect our environment and our atmosphere. However, we need to ensure that our solutions don't create new problems. The massive federal regulations that will ensue from an overarching broad climate change piece of legislation could dramatically hurt national security and our econ-

omy. The U.S. military is the country's largest consumer of oil, and 90 percent of the Federal Government energy cost comes from the military. The military has acknowledged the need to decrease their dependency on oil and they have taken proactive steps towards this by turning to hybrid electric engines, nuclear-powered ships, alternative fuels, and geothermal, wind, and solar energy.

According to a Heritage Foundation analysis, the EPA could regulate greenhouse gas emissions from numerous types of engines, including those installed in military tanks, trucks, helicopters, ships, and aircraft. Therefore, it is imperative that greenhouse gas emissions regulations must not hamper our Nation's ability to train and equip our troops by placing restrictions on our military that will be overly cumbersome.

In a time of serious economic downturn, we should be careful about advocating a regulatory policy that will raise the cost of energy and further burden businesses and consumers. Instead, we need to make sure our economy is vibrant, and we can do this by ensuring there is enough investment capital to advance alternative and energy-efficient technologies. I urge the committee to consider potential negative effects that overly stringent climate change legislation may have on our Nation's armed forces and the economy. Now is not the time to debilitate the economy or the military's ability to prepare for and engage in conflicts around the globe.

Again, thank you, Mr. Chairman, for the hearing. I look forward to hearing the testimony of our witnesses, and I yield back.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from New Jersey, Mr. Pallone.

**OPENING STATEMENT OF HON. FRANK PALLONE, JR., A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW JERSEY**

Mr. PALLONE. Thank you, Mr. Chairman.

Everyone here understands the serious threat that global climate change represents to the world. The fourth assessment report of the Intergovernmental Panel on Climate Change, IPCC, predicted serious risks and damages to species, ecosystems, and human infrastructure if action is not taken to reduce emissions.

I want to focus on the public health issues related to global warming. First, let me be clear, global warming has very real and devastating effects on public health. According to the IPCC, climate change contributes to the global burden of disease, premature death, and other adverse health impacts. Furthermore, the World Health Organization has stated that climate change is a significant and emerging threat to public health. The Organization estimates that changes in earth's climate may have caused at least 5 million cases of illness and more than 150,000 deaths in the year 2000.

As a member from New Jersey, air quality issues are a particular concern for me. The EPA designates New Jersey as a nonattainment area, meaning New Jersey has ozone levels higher than allowed under the EPA's 8-Hour Ozone National Air Quality Standard. These higher concentrations of ground ozone cause serious consequences for people with cardiorespiratory problems. Reducing global warming pollution will substantially reduce particulate mat-

ter, which would significantly benefit people living in nonattainment areas.

The goal of this hearing is to determine how best to manage the effects of global warming and how to craft an aggressive policy to lower greenhouse gas emissions. Through Chairman Markey's leadership in the Select Committee on Global Warming, we know we need aggressive action. Congress must pass legislation that will set the necessary short- and long-term emission targets that are certain and enforceable. We can't afford to wait another year to act.

Thank you, Mr. Chairman.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Georgia, Mr. Barrow.

Mr. BARROW. Thank you. I will waive an opening.

Mr. MARKEY. The gentleman waives. The chair recognizes the gentlelady from Wisconsin, Ms. Baldwin.

**OPENING STATEMENT OF HON. TAMMY BALDWIN, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF WISCONSIN**

Ms. BALDWIN. Thank you, Mr. Chairman.

We know that climate change comes with a very large price tag, and the costs are not just measured in dollars. Our emissions have put our environment, social structure, and national security at risk, and if we fail to act comprehensively, the impacts will be felt through the loss of human life, health, species extinction, and loss of ecosystems and social conflict.

As Members of Congress, especially as Members of the people's House, we are generally prone to crafting and passing legislation that provides immediate or near-term relief to our constituents just as we are doing with the recovery package this week. However, it is a seeming challenge for us to enact consequential legislation that may raise costs in the near term with benefits that aren't reaped for perhaps a generation, maybe more than a generation to come, legislation that will have benefits that some of us won't even live to see. Yet this is exactly the predicament that we now find ourselves in. Do we make the investment now to avoid the worst impacts of climate change? According to Lord Nicholas Stern, who this subcommittee heard from less than a year ago, the cost of acting today is about 1 percent of global GDP each year. However, if we wait and leave this issue to a future generation and watch the costs and risks rise, the cost of inaction rises up to 20 percent of global GDP each year. I am of the opinion that the risks are too great for us to fail to act in the very near term.

I have seen firsthand the intense rain, flooding and devastation that people in my district and across the upper Midwest area experiencing as the result of intense rainfall last year. We lost homes, businesses, and farmland, not to mention millions of dollars in lost productivity. I can only hope that we will do everything in our power to ensure that these 100-year events do not become the norm in the future.

Mr. Chairman, the scientific community has come together on this issue. It is high time that we do. I yield back the balance of my time.

Mr. MARKEY. The gentlelady's time has expired. The chair recognizes the gentleman from Vermont, Mr. Welch.

**OPENING STATEMENT OF HON. PETER WELCH, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF VERMONT**

Mr. WELCH. Thank you, Mr. Chairman, and thank you for this hearing.

For decades the issue of climate change has focused on a debate about science, but today I think that question is closed. Overwhelming scientific research shows that global warming is real, it is urgent, and it requires our immediate action. Last month we heard testimony from our country's largest corporations, and it really goes to the heart of what some of my colleagues on the other side of the aisle have been saying. We have to focus on economic consequences. The universal testimony, undivided, united opinion was that the cost of inaction would be dire to the economy, and today we will hear further that addressing climate change is critical for maintaining national security and protecting public health.

Addressing the challenge presents us with an opportunity, and that is really where we have to decide whether we are going to face this confidently the way America does when it is successful or defensively. Addressing this challenge is critical to all of us. We know it in Vermont. Even as a small State, we have realized that we can and must make a contribution to a sustainable future, and in fact, we are seeing that some of our best jobs are created by companies that are engaging in this battle directly and energetically. The test of leadership for this Congress is to face directly the realities that are difficult, and as my colleague from Wisconsin said, delay is going to cost us more, not less. We must tackle this challenge squarely and directly as the confident Nation that we are.

Thank you. I yield back.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from New York, Mr. Engel.

**OPENING STATEMENT OF HON. ELIOT ENGEL, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW YORK**

Mr. ENGEL. Thank you, Mr. Chairman, and thank you for holding this very important hearing this morning.

Climate change is real. We all know the science is no longer a debate. It is one of the greatest environmental, economic, and international security threats of our time. To protect our Nation and our environment, we must decrease our consumption of oil and increase our ability to produce clean biofuels here at home. We made progress toward these goals last Congress by enacting the Energy Independence and Security Act. That legislation made groundbreaking steps to increase CAFE standards for our vehicles, strengthen energy efficiency for a wide range of products, and promote the use of more-affordable American biofuels. I am continuing to work to advance those goals with my Open Fuel Standards Act, which would require that 50 percent of new cars sold in the United States by 2012 are flex fuel and 80 percent by 2015, meaning that they are able to run on any combination of ethanol, methanol, or gasoline.

But it is not just the transportation sector that contributes to climate change. It is much bigger than that, and that is why we are gathered here today. We must implement a cap on carbon emissions. We must work together as scientist, entrepreneurs, and Americans, simply Americans, to deploy the next generation of energy that will allow us to build the next generation's economy.

I look forward to today's hearing, and I thank you, Mr. Chairman, and I yield back.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from California, Mr. McNerney.

**OPENING STATEMENT OF HON. JERRY MCNERNEY, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA**

Mr. MCNERNEY. Thank you, Mr. Chairman. I have had the privilege of serving on your Select Committee on Global Warming, and I have seen some very incredible testimony, some stunning testimony including some from the witnesses that are in front of us today. I want to thank the witnesses for your hard work, for coming over here today, for facing this panel. I have been in business. I have seen some incredible technology out there. I know we can do this, and, you know, we have heard plenty about the choice between the economy and moving forward in reducing our electronics, that this is our going to hurt our economy. That is a false choice. We have the technology, we have the wherewithal in the United States of America to do this, and it is going to create jobs, and it is going to make us have a strong economy.

I look forward to working with members of this committee and hearing your testimony and we will end this dependence on oil and we will create a great green economy.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentlelady from California, Ms. Capps.

**OPENING STATEMENT OF HON. LOIS CAPPS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA**

Ms. CAPPS. Thank you, Mr. Chairman, for holding this hearing. I very much look forward to our esteemed witnesses' testimony.

The climate crisis is upon us. The earth is warming and the threat is real. Our economy, our national security and the public's health and well-being are all at risk. Global warming will obviously affect our economy. According to the well-respected Stern Review, every dollar we spend to reduce greenhouse gases now will save us $5 later. Already the rising sea level has left residents of a small village in northwest Alaska unable to fish, unable to build safe homes, and that is just one example.

In my home State of California, a study by the economists from the University of California Berkley found that $2.5 trillion worth of real estate assets are vulnerable to flooding and sea rise. In addition, $500 billion of transportation facilities are at risk as a result of rising sea levels, including five major California airports that sit on the coast. One of these airports is the Santa Barbara Airport that I fly in and out of each week.

The climate crisis also threatens our national security. Policy analysts have issued several reports finding that a failure to act will

have dire consequences triggering humanitarian disasters and political instability in what are already some of our most fragile regions such as Africa and the Middle East.

Finally, as a public health nurse, as the grandmother of a child with asthma, I am gravely concerned about the effect of global warming on the public's health. For example, rising temperatures increase ozone smog, which worsens the condition of people suffering from respiratory diseases like asthma. Increased levels of carbon dioxide may prolong the pollen season, intensifying the suffering of the 36 million American plagued with seasonal allergies. Increased temperatures have also caused extreme heat waves with tragic consequences. In July 2006, an extreme heat wave in California caused at least 140 deaths. Our sources of clean drinking water are also at risk, especially again in California. Many of my constituents rely on the Colorado River for a portion of their drinking water. The river faces long-term drought due to global warming and it is estimated that it would take 15 to 20 years of normal rainfall to refill the river's main reservoirs.

We need to address this situation. I am thankful that this process is beginning today.

Mr. MARKEY. The gentlelady's time has expired. All opening statements by members of the subcommittee have been completed. I note that a member of the full committee, Ms. Christensen from the Virgin Islands, is here, and if you would like by unanimous consent, is there a 1-minute statement you would like to make at this time?

**OPENING STATEMENT OF HON. DONNA M. CHRISTENSEN, A REPRESENTATIVE IN CONGRESS FROM THE VIRGIN ISLANDS**

Ms. CHRISTENSEN. Thank you, Mr. Chairman and Ranking Member, and thank you for allowing me to sit in on the hearing, and I would like to associate myself with the remarks of my colleague, Ms. Capps from California, but I also wanted to point out that while climate change is an important issue for everyone everywhere, it is especially critical to the Caribbean, where my district sits, and despite the fact that we contribute relatively little to greenhouse gases, we are likely to face the severest of impacts, and also the reports have shown that the cost of inaction for us is unsustainable; so I look forward to the testimony of our witnesses.

Mr. MARKEY. I thank the gentlelady, and we thank her for visiting with us today.

That completes all opening statements. We will now turn to our very distinguished panel, and I will begin by recognizing our first witness, who is Dr. Daniel Schrag. He is the Director of the Center for the Environment and the director of the Laboratory for Geochemical Oceanography at Harvard University. He is a former member of the board of reviewing editors for Science magazine, and a MacArthur fellow, a winner of that genius award. We look forward to your testimony, Dr. Schrag. Whenever you are ready, please begin.

**STATEMENT OF DANIEL SCHRAG, DIRECTOR OF THE CENTER FOR THE ENVIRONMENT, DIRECTOR OF THE LABORATORY FOR GEOCHEMICAL OCEANOGRAPHY, HARVARD UNIVERSITY**

Mr. SCHRAG. Thank you, Mr. Chairman. As an earth scientist who studies how the climate has changed in the past, I believe the geologic data suggests that most scientific assessments of global warming err on the conservative side. This has led to a misunderstanding of the risk of adverse impacts of climate change. I will give a few examples today.

[Slide shown.]

To quickly remind the committee, and if you could click once on the slide, humans are changing the amount of carbon dioxide in the atmosphere, mostly from burning coal, oil, and gas. The current level, more than 380 parts per million, is higher than it has been for at least the last 650,000 years and perhaps for tens of millions of years. By the middle of this century, we will be at 500 parts per million. The issue before us is not whether we will get to 500, but whether we stop at 500 or go to 1,000. It is an uncontrolled experiment filled with uncertainty, and just like uncertainty in financial markets, it is a reason for grave concern.

Observations and models tell us that climate change in this century may be dramatic, perhaps even catastrophic. We tend to focus on the more extreme and more adverse consequences, not because we are aware of any beneficial outcomes, but simply because global warming is like an insurance problem. We need to understand the probability of the most undesirable outcomes to best gauge what steps to take to avoid them. I will give two examples of how conservative the scientific community can be. Next slide.

[Slide shown.]

First, consider the sea ice distribution in the Arctic in September of 2007. Previous studies, including the IPCC, predicted that the Arctic icecap might disappear in the summer toward the end of the century, certainly no earlier than 2050. Then in 2007, there was a 20 percent decline in aerial extent of sea ice below the previous record, which was 2005. New studies now predict that the Arctic may be ice-free as soon as the middle of the next decade, a milestone that will drastically change the Arctic climate, will change world commerce, and will enhance the melting of land ice on Greenland because the Arctic sea ice keeps Greenland cold.

[Slide shown.]

A second example, next slide, is the IPCC's discussion of future sea level rise. The IPCC predicts 10 to 25 inches based on different emission scenarios of overall sea level rise, but most of that is actually due to the thermal expansion of seawater. Only 2 inches over the century are attributed to melting of Greenland, even though Greenland ice has about 23 feet of potential sea level rise stored on it. The projection is an extrapolation of the current rates of warming, assuming that the current melting of Greenland will go on and stay the same throughout the century with no change, a highly unlikely outcome. It illustrates the basic problem. When pushed, the scientific community often falls back on an answer that can be defended with confidence, even though it may not provide

you, the policymakers, with an accurate picture of the risk involved.

Why are scientists so conservative in their assessment of climate change? A major reason is that the scientific method teaches us to be conservative and to state things only when we know them with high confidence, such as 95 percent confidence interval. This is in striking contrast to questions of national security, as illustrated by the 1 percent doctrine articulated by former Vice President Cheney. In Cheney's formulation, if a probability of a high-consequence event such as nuclear terrorist attack is only 1 percent, then we should treat it as an absolute certainty and act accordingly. It is really just an extension of the precautionary principle. But climate change may have just as serious implications for national security. Consider the advance of the timing of mountain snowmelt as the earth warms.

[Slide shown.]

In the western United States, next slide, please, this could mean as much as 60 to 80 days earlier snowmelt than today by the end of the century, and again, this could be conservative. If the river draining the Sierra Nevada in California, for example, were to run dry by mid-summer, then California agriculture would be impossible, and this is mild compared with other parts of the world. The great rivers that drain the Himalayas and Tibetan plateau, the Indus, the Ganges, the Mekong, the Yangtze, and the Yellow all depend on melting snow and ice for a large fraction of their water. How might the decline of the Indus, for example, affect the political stability of Pakistan and the support for Islamic terrorism? How will China and India deal with reduced water resources, and will it lead to more regional conflict? The risk of serious water stress, not just in Asia but around the world, contributing to failed states and major security disasters is well above a 1 percent threshold for serious action and illustrates how global warming poses an enormous challenge to peace and stability around the world.

A final point I would like to make before this committee is that many steps to mitigate climate change will also result in an increase in our national security. Energy security is at the heart of many issues of security around the world including funding our enemies or the strengthening influence that Russia has over Europe, because of dependence on natural gas imports. Most new technologies that can reduce carbon emissions will also reduce our dependence on foreign sources of fossil fuels. Energy efficiency is the most important strategy as it will likely result in significant savings to our economy. Investments in renewable energy resources in appropriate locations, as well as carbon capture and storage for coal-fired power plants and other large stationary sources of $CO_2$, will reduce our need to import greater amounts of liquid natural gas in the future. And our dependence on foreign oil will only be reduce in the long run if we can develop clean, domestic alternatives such as synthetic fuels produced from blending biomass and coal with carbon sequestration. Through such steps we can lead the rest of the world down a path toward greater prosperity, stability, and security. If we fail in this task, we risk threatening the stability of our climate, our society and our entire planet. Thank you.

[The prepared statement of Mr. Schrag follows:]

**Testimony of Professor Daniel P. Schrag, Harvard University**
**before the**
**Energy and Environment Subcommittee of the**
**House Committee on Energy and Commerce**
**U.S. House of Representatives**
February 12, 2009

Thank you, Mr. Chairman, and thank you to the members of the committee for inviting me to speak here today. I am Sturgis Hooper Professor of Geology at Harvard University in the Department of Earth and Planetary Sciences and Professor of Environmental Sciences and Engineering in the School of Engineering and Applied Sciences. I also serve as Director of the Harvard University Center for the Environment, which allows me to work with faculty in public health, public policy, economics, business, law and a variety of other disciplines.

One of the issues before this committee today is how global warming will contribute to national and international security. I approach this question from my work on the science of the climate system, and also from my studies of new and traditional energy technologies. As an earth scientist who studies how the climate has changed in the past, I believe there is no serious debate about whether the earth will warm as carbon dioxide levels increase over this century – it will. What is difficult to predict is exactly how much warming will occur, and exactly how that will affect human society. Unfortunately, I believe that most scientific assessments of future climate change may err on the conservative side, contrary to the claims of the few but vocal climate skeptics. This has led to a misunderstanding of the risk of adverse impacts of climate change. I will give a few examples today.

Humans are changing the amount of carbon dioxide in the atmosphere, mostly from burning of coal, oil and gas, with deforestation also playing a significant role. The current level, in excess of 380 parts per million (ppm), is higher than it has been for at least the last 650,000 years, and perhaps for tens of millions of years. To put it differently, we are experiencing higher $CO_2$ levels now than any human being has ever seen in the history of the earth; and over the next 100 years, without substantial changes in the trajectory of energy technology or economic development, we will see atmospheric $CO_2$ rise to more than 800 ppm, roughly triple the pre-industrial level. Carbon dioxide is a greenhouse gas. Its presence in planetary atmospheres causes warming of planetary surfaces; an extreme

example is the $CO_2$-rich atmosphere of Venus, which is responsible for its surface temperature in excess of 460 °C.

The question that confronts us now is how the rise of $CO_2$ on this planet will affect our climate, not over millions or even thousands of years but over decades and centuries. We know that, coincident with the unprecedented rise in $CO_2$ over the last century, we have seen a rise in global temperatures. We know from Lonnie Thompson's work on tropical glaciers as well as many other studies that this warming is not related to any natural cycle. But this does not address the question of what will happen as $CO_2$ levels continue to rise. To answer this question, climate scientists have constructed models that represent the best understanding of the climate system from the last century of observations. These models tell us that climate change in this century may be dramatic, and perhaps even catastrophic. The models predict winners and losers for smaller magnitudes of change, such as mild changes in temperature or precipitation, but nearly all societies will be adversely affected by the more extreme changes that are possible including the collapse of one of the large polar ice sheets, or a large decline in mountain snowmelt. Other predictions that would pose serious challenges for societies include changes in the frequency and intensity of large storms, changes in patterns of precipitation that could lead to more severe droughts or extreme flooding, increases in peak temperatures that could drastically reduce agricultural harvests, and also ecological changes that affect ecosystems crucial to human society. In assessing future climate change for policy makers, we tend to focus on the more extreme and more adverse consequences not because we are unaware that there may be some beneficial outcomes, but simply because global warming is like an insurance problem. We need to understand the probability of the most undesirable outcomes to best gauge what steps to take to avoid them.

It is important to understand that the climate models we use to predict the future are not perfect – but this is not surprising as they are attempting to make predictions about an atmospheric state that no human being has ever seen. They remain an essential tool for exploring future scenarios, but we must also consider evidence for climate change from the geologic past. This is the major area of my research. I will not cover it today in much detail, but let me simply say that lessons from earth history are surprisingly consistent, whether from warm climates or cold, whether over millions of years or thousands. The data suggest that our real climate system is likely to be more sensitive than the models, and that there is a significant risk that future climate change will be more severe than most models now predict.

A second lesson from the study of past climates is that climate changes are not always slow and steady, but can occur in decades or even years. For example, the abrupt changes of as much as 35°F over less than a decade observed in Greenland ice cores during the last glacial period, with smaller effects throughout the Northern hemisphere, are spectacular examples of how quickly regional climate can change. The mechanisms responsible for such changes during the ice age probably required greater extent of land glaciers and sea ice than exist today, and so are unlikely to be experienced in exactly the same way over the next century. However, there are a number of possible mechanisms that can lead to abrupt and irreversible change in the climate system and may be very important over the next several decades. One is the response of glaciers on Greenland and Antarctica to enhanced polar warming over the next century. We do not know enough about glacial melting to be able to predict whether these ice sheets will decay smoothly, or whether there is the possibility for very rapid collapse. Another potential tipping point is the roughly 500 billion tons of carbon stored in permafrost in the tundra regions, particularly in Siberia. As those soils warm, microbes release the carbon as greenhouse gases – either methane or $CO_2$. Such a release would be a disaster if it happened quickly as it would overwhelm any emission reduction program we might implement.

Another important point in assessing the risk of catastrophic climate change is the large inertia in our climate system. $CO_2$ resides in the atmosphere and surface ocean for centuries, only slowly taken up by the deep ocean. If we were to reduce our emissions to zero immediately, it would take more than 200 years for terrestrial and oceanic uptake of carbon to restore the atmosphere to its pre-industrial condition. Even if we could stabilize $CO_2$ levels immediately, the current atmosphere with more than 380 ppm may be too warm to allow the ice sheets on Greenland or West Antarctica to survive. In addition, the oceans will continue to warm for decades even if emissions were halted. Thus, there is great inertia in the climate system, in the heat capacity of the oceans, in ice sheets, and in the residence time of carbon dioxide in the atmosphere (and in the lifetime of our energy infrastructure), all of which make substantial climate change inevitable. What this means is that we cannot wait until we actually see a disaster before we work on a solution. By the time we know whether the most extreme consequences of climate change will occur, it may well be too late to stop them.

Two examples of predictions by the climate community are particularly poignant in explaining how the scientific community tends to be conservative and also why

climate surprises will often be in the adverse direction, towards more rapid and more extreme change. First, consider the sea ice distribution in the Arctic in September of 2007. Previous studies, including the Intergovernmental Panel on Climate Change (IPCC), predicted that the Arctic ice cap would disappear in the summer towards the end of the century, certainly no earlier than 2050. Then, in 2007, there was a 20 percent decline in areal extent of sea ice beyond the previous record (which was 2005). New studies predict that the Arctic may be ice free as soon as the middle of the next decade, a milestone that would drastically change the Arctic climate and enhance the melting of land ice on Greenland. Even Arctic scientists who had watched the decline in the ice cap for 20 years were amazed by such a rapid deterioration – and there are reasons why we now expect this process to accelerate.

A second example of a conservative climate prediction is the IPCC's discussion of future sea level rise. Most of the 10 to 25 inches predicted under different emissions scenarios results simply from the thermal expansion of seawater. Only two inches over the century are attributed to melting of ice on Greenland, despite the fact that the Greenland ice sheet would raise sea level by 23 feet if it melted in its entirety. This projection is equivalent to saying that the Greenland ice sheet will continue melting at exactly the same rate as it is melting today with no change as the Earth continues to warm, a highly unlikely outcome. This illustrates the basic problem with scientific assessments under such large uncertainty. When pushed, the scientific community often falls back on an answer that can be defended with confidence, even though it may not provide policy makers with an accurate picture of the risk involved.

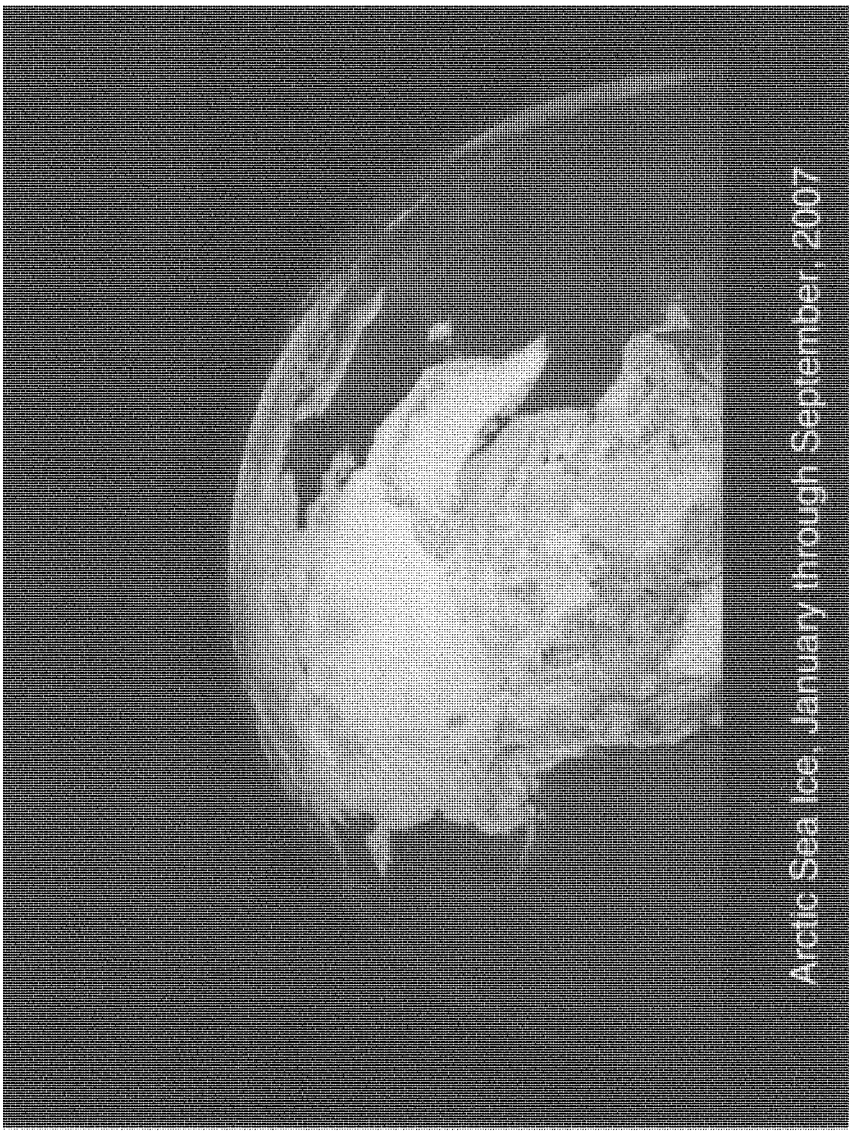
Why do scientists tend to be conservative in their assessment of climate change? A major reason is that the scientific method teaches us to be conservative, and to state things only when we know them with high confidence, i.e., 95% confidence intervals. This is in striking contrast to another approach to risk and uncertainty in questions of national security – an approach called the "one percent doctrine", articulated by former Vice President Cheney. In Cheney's formulation, if the probability of a high consequence event such as a nuclear terrorist attack is only one percent, then we should treat it as an absolute certainty and act accordingly. To many, the Cheney doctrine is an extreme version of the precautionary principle, and yet it underscores how climate change has been treated quite differently than other matters of national and international security.

It is quite clear that climate change may have just as significant an effect on national security as many other concerns more traditionally in the spotlight of the security community. For example, one prediction of climate models – again,

possibly on the conservative side – is that global warming will advance the timing of summer snow melt from mountains that serve as natural reservoirs for many parts of the world. In the western U.S., this could mean as much as 60 to 80 days earlier than today. Consider the agricultural capacity of California's central valley, which depends on rivers that drain the snowpack in the Sierra Nevada. If, by the end of this century, these rivers run dry by mid-summer, instead of lasting through the fall, then California agriculture as we know it today would be impossible. But this would be mild compared with the impacts on major river systems around the world. The great rivers that drain the Himalayas and Tibetan plateau – the Indus, the Ganges, the Mekong, the Yangtze, and the Yellow – all depend upon melting snow and ice for a large fraction of their water. Many of the three billion people who depend on these rivers are already under water stress, in part due to unsustainable practices of mining groundwater. How might the decline of the Indus affect the political stability of Pakistan and the support for Islamic terrorism? How will China and India deal with reduced water resources, especially when each is suspicious of efforts by the other to control the critical regions that represent the headwaters for their river systems? The risk of serious water stress, not just in Asia but around the world, is well above a one percent threshold for serious action, and illustrates how global warming poses an enormous challenge to peace and stability around the world.

A final point I would like to make before this committee is that many steps to mitigate climate change will also result in an increase in our national security. In addition to their impact on the climate system, fossil fuels – in particular petroleum and natural gas – represent a major cause of security concerns around the world including the geopolitics of oil, funding our enemies, and the strengthening influence that Russia has over Europe because of dependence on natural gas imports. Most new technologies that can reduce carbon emissions will also reduce our dependence on foreign sources of fossil fuels. Energy efficiency is the most important strategy, as it will likely result in significant savings to our economy. Investments in renewable energy sources in appropriate locations, as well as carbon capture and storage for coal-fired power plants and other large, stationary sources of $CO_2$ will reduce our need to import greater amounts of liquid natural gas in the future. And our dependence on foreign oil will only be reduced in the long run if we can develop clean, domestic alternatives such as synthetic fuels produced from biomass and coal with carbon sequestration. Through such steps, we can lead the rest of the world down a path towards greater prosperity, stability and security. If we fail in this task, we risk threatening the stability of our climate, our society, and our entire planet.

Atmospheric $CO_2$ has never been higher than 300 ppm in the last 650,000 years (perhaps not in the last 35 million years)
2040 to 2060
2009
Atmospheric CO2 (ppmv)
Age (years before present)
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0


Arctic Sea Ice January through September, 2007

Rate of mass change between April, 2002 - June, 2007.

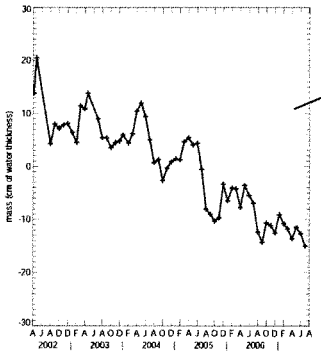
Rate of Ice volume change:

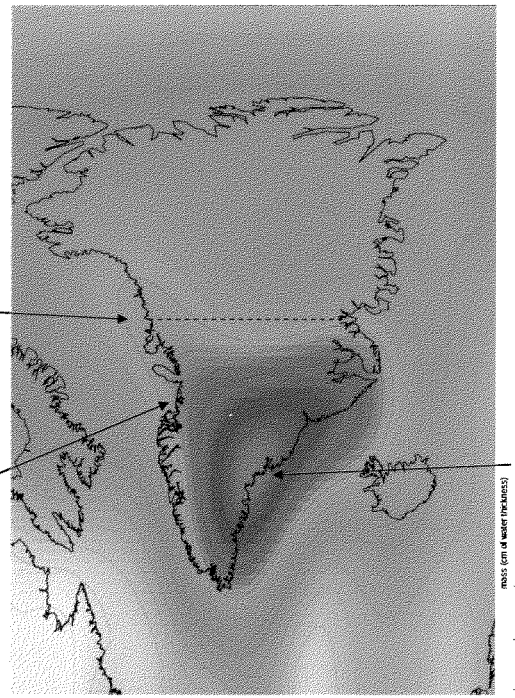
All Greenland: -238 km$^3$/yr

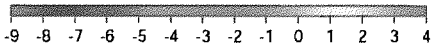
South Greenland: -164 km$^3$/yr

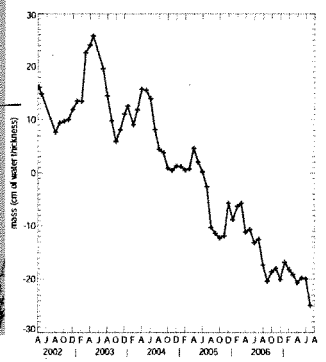
North Greenland: -65 km$^3$/yr

73.25$^0$ N

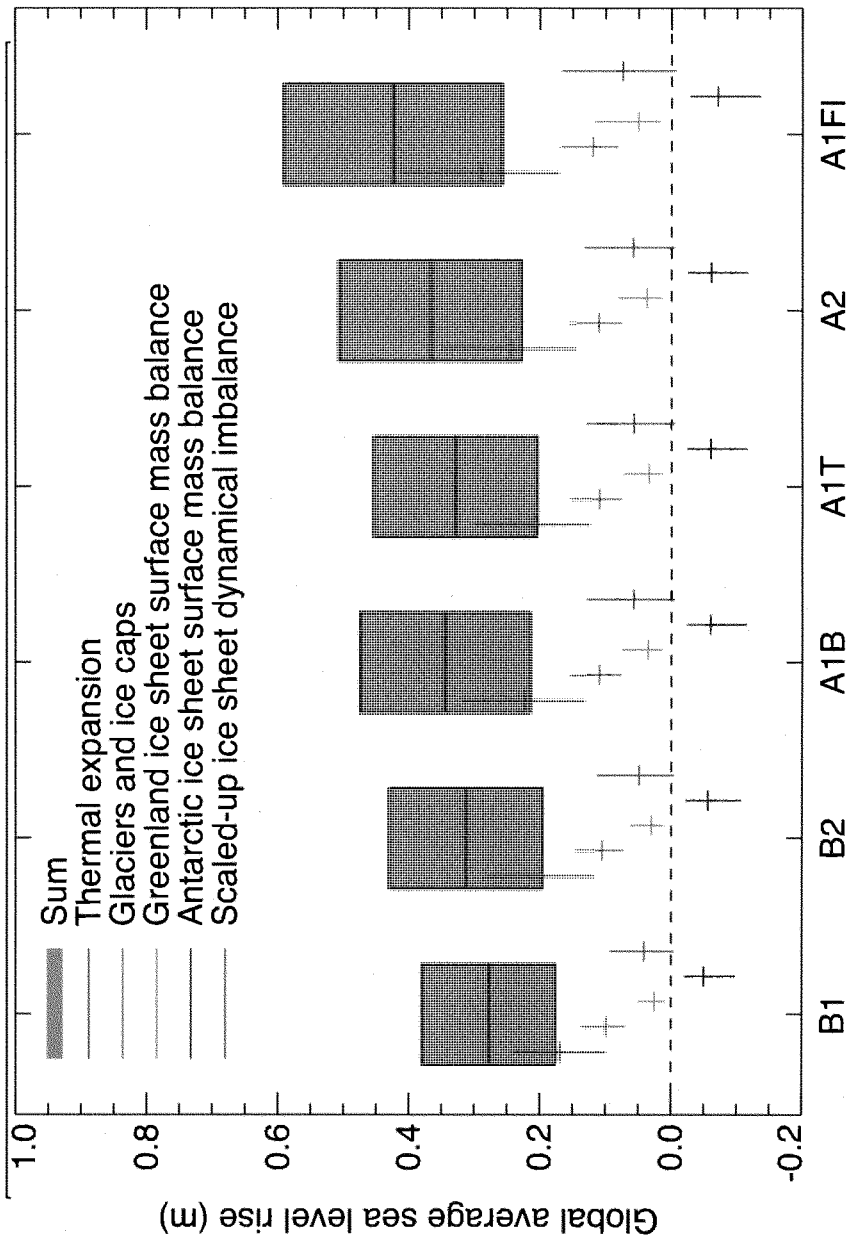




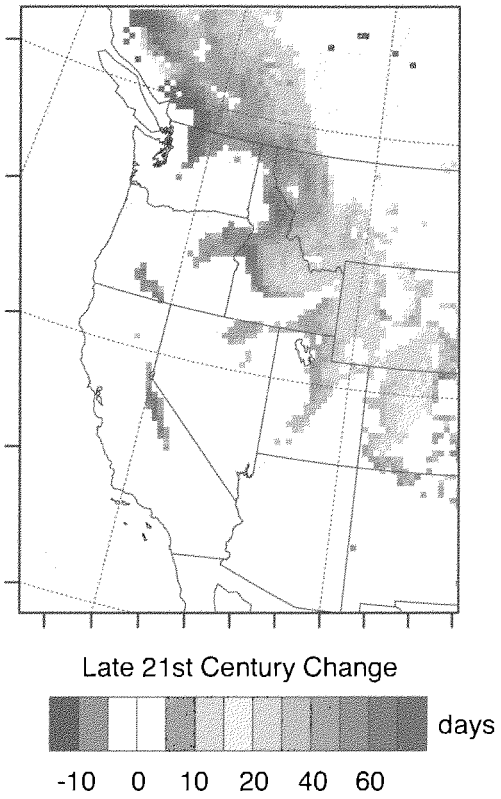




-238 km$^3$/yr = 0.5 mm/yr sea level rise


Global average sea level rise (m)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Sum
Thermal expansion
Glaciers and ice caps
Greenland ice sheet surface mass balance
Antarctic ice sheet surface mass balance
Scaled-up ice sheet dynamical imbalance
B1
B2
A1B
A1T
A2
A1FI

Are the polar ice sheets vulnerable?
Greenland: 7 meters sea level equivalent
West Antarctica: 6 meters sea level equivalent
East Antarctica: 50 meters sea level equivalent
We do not know how fast it will take to melt these
massive ice sheets. 1000 years? 500 years? 200 years?

# Snow-Dominated Runoff




(Raucher et al., 2008)

Mr. MARKEY. Thank you, Professor Schrag, very much.

Our second witness is General Gordon Sullivan, who is the President and Chief Operating Officer of the Association of the United States Army, and a former chief of staff of the U.S. Army. He headed the Military Advisory Board for the Center for Naval Analysis Corporation's report on national security and the threats of climate change. We are honored to have you with us, General Sullivan. Please proceed when you are ready to go.

**STATEMENT OF GENERAL GORDON R. SULLIVAN (RET.), PRESIDENT AND CHIEF OPERATING OFFICER, ASSOCIATION OF THE UNITED STATES ARMY**

General SULLIVAN. Thank you, Mr. Chairman and Ranking Member.

Two years ago I appeared before the first meeting of the Select Committee on Energy Independence and Global Warming in my capacity as the chairman of the Military Advisory Board for CNA reporting on national security and the threat of global climate change. The advisory board consisted of three- and four-star flag and general officers from all four services. Mr. Chairman, I request that this report be once again entered for the record.

Mr. MARKEY. Without objection, so ordered.

[The information appears at the conclusion of the hearing.]

General SULLIVAN. Our charge was to learn as much as we could in a relatively short period of time about the emerging phenomenon of global climate change using our experience and expertise as military leaders to process our learning through a national security lens. In other words, we were asked, what are the national security implications of global climate change.

In summary, what I reported at that time is the following. First, global climate change is a serious threat to our national security. Second, climate change will be what we call a threat multiplier. In many areas of the world that will be hardest hit by climate change, impacts are already being stressed by lack of water, lack of food and political and social unrest. Global climate change will only magnify those threats. Third, projected climate change will add to tensions even in stable regions of the world, and lastly, climate change, national security and energy dependence are a related set of global challenges.

In the 2 years since I appeared before this committee, we have seen no evidence to contradict those findings. In fact, we have only seen the findings confirmed and reinforced.

In concurrence with one of our recommendations, a National Intelligence Assessment on global climate change was conducted by the National Intelligence Council. The NIA remains classified but public accounts of the assessment suggest very strong agreement with our findings. Since our report, the scientific community including the Intergovernmental Panel on Climate Change has also continued their important work in examining climate change. What we have learned from their most recent work is that climate change is occurring at a much faster pace than the scientists previously thought it could. The Arctic is a case in point. Two years ago scientists were reporting as has been stated here twice already that the Arctic would be free from ice within about 40 years. Now

they are telling us that it will happen in a couple of years. As a matter of fact, the northern part of the Bering Sea is now free of ice. The acceleration of the changes in the Arctic is stunning.

The trends of climatological data and concrete evidence of change continue to suggest the globe is changing in profound ways. I am not a scientist, nor are most of my colleagues on the Military Advisory Board. I would characterize us as military professionals accustomed to making decisions during times with ambiguous information with little concrete knowledge of the enemy intent. We base our decision on trends, experience, and judgment. We know that demanding 100 percent certainty during a crisis could be catastrophic and disastrous.

And so we ask, quo vadis? Where do we go? I ask it in Latin because I believe it is a very fundamental question for the United States of America. Where we go will be a reflection of how we feel about the world in which we live. I feel right now we are drifting—excuse the metaphor—in uncharted waters. This is not the time to wait for 100 percent certainty. The trends are not good.

What can guide us in choosing our path is up to you. I believe there is a relationship between energy dependence, climate change, economic revitalization, and our national security. These are deeply related issues. When we consider investments in one, we must consider the impact on the whole.

My personal view is that the United States of America is obliged to play a leadership role in this area. Leadership by the United States will be key. The best opportunity for us to demonstrate our global leadership on this issue is in Copenhagen, and I do believe we must take bold and swift steps even here at home to gain the credibility necessary to participate in those discussions with credibility.

We must show leadership in developing energy alternatives that reduce our need for fossil fuels.

Thank you, Mr. Chairman.

[The prepared statement of Gen. Sullivan follows:]

STATEMENT OF GENERAL GORDON R. SULLIVAN, USA (RET.)

Chairman Markey, members of the Committee, thank you for the invitation to offer my testimony today. My last duty position was as Army Chief of Staff. I retired from active service in 1995 and am now the President of the Association of the United States Army.

Two years ago, I appeared at the first meeting of the Select Committee on Energy Independence and Global Warming in my capacity as Chairman of the Military Advisory Board to the CNA report on "National Security and the Threat of Climate Change." The Military Advisory Board consisted of 3- and 4- star flag and general officers from all four Services. Mr. Chairman, I request that this report be entered for the record.

Our charge was to learn as much as we could in a relatively short period about the emerging phenomenon of global climate change using our experience as military leaders to process our learning through a National Security lens. In other words, what are the national security implications of climate change?

In summary, what I reported then was that:

- First, climate change is a serious threat to our national security.
- Second, climate change will be what we called a "threat multiplier". Many areas of the world that will be the hardest hit by climate change impacts are already being stressed by lack of water, lack of food, and political and social unrest. Adding climate change to this mix will only serve to exacerbate the existing instabilities.
- Third, projected climate change will add to tensions even in stable regions of the world.

• And fourth, that climate change, national security and energy dependence are a related set of global challenges.

In the 2 years since I appeared before the Committee, we've seen no evidence to contradict those findings. In fact, we've only seen them reinforced.

In concurrence with one of our recommendations, a National Intelligence Assessment on global climate change was conducted by the National Intelligence Council. The NIA remains classified, but public accounts of the assessment suggest very strong agreement with our findings.

Since our report, the scientific community, including the Intergovernmental Panel on Climate Change, has also continued their important work in examining climate change. What we have learned from their most recent work is that climate change is occurring at a much faster pace than the scientists previously thought it could. The Arctic is a case-in-point. Two years ago, scientists were reporting that the Arctic could be ice-free by 2040. Now, the scientists are telling us that it could happen within just a few years. The acceleration of the changes in the Arctic is stunning.

The trends of climatological data and concrete evidence of change continue to suggest the globe is changing in profound ways. I am not a scientist, nor are most of my colleagues on the Military Advisory Board. I would categorize us as military professionals accustomed to making decisions during times of uncertainty. We were trained to make decisions in situations defined by ambiguous information and little concrete knowledge of the enemy intent. We based our decisions on trends, experience, and judgment. We know that demanding 100% certainty during a crisis could be disastrous.

And so we ask: Quo vadis? Where do we go? I ask it in Latin because I mean to imply that it's a fundamental question. Where we go will be a reflection of our values. Right now, we are drifting off into uncharted waters. This is not the time to either wait for 100% certainty or simply hope our environment is not changing.

What can guide us in choosing our path is an understanding of the interrelated nature of these issues. Energy dependence. Climate change. Economic Revitalization. National Security. These are deeply related issues. As we consider investments in one, we must consider their impact on the whole.

My personal view is that the US is obliged to play a leadership role: Leadership by the US is key. The best opportunity for the US to demonstrate our global leadership is in Copenhagen, but I do believe we must take bold and swift steps here at home if we're to have the credibility necessary to lead in those important negotiations.

We must also show leadership on developing energy alternatives that reduce our reliance on fossil fuels from unstable regions of the world, reduce our energy consumption, and improve our nation's energy posture. That is the subject of the Military Advisory Board's next report on energy security and America's defense. I am hopeful that this report, which we will release soon, will make an important contribution to the national effort to retool America by advancing low carbon energy solutions that improve our nation's energy and national security posture.

I'll close with another reminder of something I said two years ago. I reflected on decades of service - working along side many great public servants who worked hard and risked their lives to protect our country. And I had begun to see that our country is now being threatened by a different kind of enemy. I'm here today as a retired military leader, making a case for you to consider climate change and energy dependence as national security threats. But I don't want to skate past this last point. What this country looks like, what it feels like to live here, will also be changed. Tapping sugar maples in New England winters. Fishing off the Cape. Those were images I held close when stationed overseas. Those images were important to a solider. I hope they're important to Members of Congress.

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Mr. MARKEY. We thank you, General.

Our next witness is Mr. James Woolsey. Mr. Woolsey is a venture partner with VantagePoint Venture Partners in San Bruno, California, and serves on the National Commission on Energy Policy. He is also a senior executive advisor for Booz Allen Hamilton. He has served presidential appointments in both Democrat and Republican administrations, most recently as Director of the Central Intelligence Agency. Thank you, Mr. Woolsey, for being with us here today. Whenever you are ready, please begin.

**STATEMENT OF R. JAMES WOOLSEY, VENTURE PARTNER, VANTAGEPOINT VENTURE PARTNERS, FORMER DIRECTOR, CENTRAL INTELLIGENCE AGENCY**

Mr. WOOLSEY. Thank you, Mr. Chairman. It is an honor to be with you.

The subject of the hearing suggests that energy in the current environment needs to be secure, needs to be clean, and needs to be affordable, and in moving in that direction, we have to keep in mind, I think, two different types of threats to our security. One is what a colleague of mine calls malevolent as distinguished from malignant. A malevolent threat is one that someone plans, and with respect to our energy infrastructure, probably the two most dangerous are dependence on oil from the Middle East and the results of four funding both sides of the War on Terror and on and on, a set of issues I don't need to go into detail with this committee.

But the electricity grid is another extraordinarily vulnerable part of our system. A National Academy of Sciences study of 2002, which I participated in, said simultaneous attacks on a few critical components of the grid could result in a widespread and extended blackout. Conceivably, they could also cause the grid to collapse with cascading failure in equipment far from the attacks, leading to an even larger long-term blackout, and may I say, Mr. Chairman, if we had a serious attack on the grid either by way of cyber attacks or by way of physical attacks, and we lost a chunk of it, we are not back in the 1970s in the pre-Internet Web days; we are back in the 1870s in the pre-electricity era. That set of issues has not been successfully addressed in the last 7 years since we wrote for the National Academy of Sciences.

If we look at malignant threats, threats no one is trying to create but which come about because of the complexity of systems, there are a number, and one, I think, of the most serious is certainly climate change. That issue is dealt with in pages 2 through 9 of the attached chapter of the book which the staff has kindly allowed me to attach to my testimony, and I will simply say that I believe Professor Schrag summarized those issues extremely well. We have a habit from the non-scientific community of looking at change as if it is linear, whereas, in fact, some of the most troubling changes can be exponential and particularly in this climate area, it is difficult for us to get our minds around it.

The other is that we don't need to believe that all of climate change is anthropogenic, is caused by human beings, in order to believe that it is a serious problem. The world may well be in the middle of a several-thousand-year warming trend now for historic reasons. The world's climate has changed many times. But we are certainly doing something quite serious to it by doubling, tripling and more than tripling the amount of $CO_2$ in the atmosphere. I think that one needs to keep in mind that one needs to remember both these malignant and these malevolent problems as one makes progress. We don't want, for example, to deal with climate change in a way that enhances the vulnerability of the electricity grid.

As a device to illustrate this, the last seven pages or so of the attached chapter of mine is a dialog between a tree hugger and a hawk. My tree hugger is the ghost of John Muir and my hawk is the ghost of George S. Patton. Muir is concerned only about carbon.

Patton is concerned only about terrorism. What they keep finding is that on many proposals they are able to agree on what to do even though they are not doing it for the same reasons. For example, energy efficiency in buildings, so look at what Walmart has been able to do. Patton and Muir agree on that. Combined heat and power, generating huge amounts of electricity from waste heat—Denmark gets a third of its electricity from waste heat. We get a tiny percent, just because of policies by the public utility commissions. Patton and Muir agree on that. Distributed generation encouraged by such steps as the German feed-in tariff, which Congressman Inslee and others are working on here, can help us move toward renewables substantially. Decoupling revenues from earnings for electric utilities, as California did 20-plus years ago and a few States have followed since, can add a substantial set of incentives toward energy efficiency. Moving toward flexible fuel vehicles, as Congressman Engel has suggested, as Brazil has done, making the fuels out of cellulosic and waste feedstocks and to some extent turning toward electricity as in plug-in hybrids and electric vehicles, all of these matters, Patton and Muir in my construct find great common cause in. Interestingly enough, Muir is more open to adding large power plants either from renewables or from coal with carbon capture and sequestration, assuming it is successful, or from nuclear than is Patton because Patton says I don't want to add to the electricity grid. He says the electricity grid is much more vulnerable than the Maginot Line. The Maginot Line could at least be defended from one direction. The way we are going about it now, the grid can't be defended at all.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Woolsey follows:]

U.S. House of Representatives

Committee on Energy and Commerce

Subcommittee on Energy and Environment

Hearing on

The Climate Crisis:

National Security, Public Health, and Economic Threats

February 12, 2009

Testimony of R. James Woolsey

Mr. Chairman and members of the Committee, it is an honor to testify before you today on these important issues. After discussing it with the Committee's staff I have attached to this short statement as a fuller treatment of the issues a chapter that I contributed to a book published a few months ago by the Brookings Institution on climate change and national security, since it deals directly with these matters. By way of identification, I am currently a venture partner in the California Venture Capital firm, VantagePoint, and also the Annenberg Distinguished Fellow at Stanford University's Hoover Institution. In both of these capacities I work on issues related to renewable energy and energy security. Earlier I practiced law in Washington for 22 years, was a consultant for five, dealing principally with energy issues, and served in the U.S. Government on five occasions for twelve years, all in fields related to national security. I have held Presidential appointments four times, twice in Democratic and twice in Republican administrations.

The title of these hearings suggests, I think accurately, that as we decide on our energy policies, and other policies that can affect the biosphere and the climate, we must keep in mind that energy needs to be as secure, clean, and affordable as possible. If we ignore any of these criteria the problem may seem to get much easier to solve – we could have all our

energy come from secure domestic sources, for example, if we don't care how dirty or expensive they are – but we would not be serving the public to the degree we should.

With respect to security, my former colleague, Rachel Kleinfeld, once suggested a distinction that I find very useful – that between malevolent and malignant threats. We must deal with both. Malevolent threats are those that are the product of human choice – the choice that terrorists might make to attack our electricity grid or oil production facilities in the Middle East, the choice that the government of Iran makes to use its oil revenues to develop nuclear weapons, the choice the government of Saudi Arabia makes to give billions of dollars of oil revenues to the Wahhabi sect which in turn uses them, inter alia, to disseminate extraordinarily hate-filled educational materials all over the world, including in the U.S.

Malignant threats, on the other hand, are those that are associated with the collapse of a complex system – the electric grid, a human body, the globe's climate – when it is unintentionally disturbed in some way. No one was trying to cause a power outage for 50 million people when a tree branch touched a power line in Cleveland in August of 2003, and we are not trying to raise sea levels to a damaging degree during the lives of our grandchildren by continuing to operate coal-fired power plants and gasoline-fueled SUVs. Yet we may well be doing so.

Mr. Chairman, I realize there is not unanimity in the Congress on the issue of whether human activity – the destruction of rainforests, the burning of fossil fuels – contributes significantly to climate change. I believe that it does, but not that human activity is the sole contributor to such change. I think it is important for us to recognize a number of aspects of this subject, spelled out in more detail in the attached chapter.

First, not all change is linear nor is it dealt with readily by mathematical models. Tipping points and exponential change occur in climate as well as other aspects of nature. For example, about 125,000

years ago, between the last two ice ages, the earth was only, on average, about one degree centigrade warmer than it is today but sea levels were about five meters higher. A sea level rise of five meters would be an almost unimaginable catastrophe for humanity.

Second, it is not necessary to believe that all climate change is caused by humans to believe that we may negatively affect the situation by our behavior. Even if the earth is in a warming trend due to natural causes we can make the problem worse by doubling or tripling the amount of CO2 in the atmosphere. If an individual is genetically inclined to have lung cancer it is still not wise for him to decide to smoke five packs a day.

Finally, if we concentrate on cost and security as well as the environment we may find that technology and a willingness to work together is offering us some opportunities to improve all three. The last third of the attached chapter is an invented dialogue between a tree hugger and a hawk, trying to come up with an energy policy for the U.S. My imagined tree hugger is the ghost of John Muir – the father of the national park system and the environmental movement – and my hawk is the ghost of George S. Patton, Third Army Commander in WW II. Muir is only concerned with carbon and Patton only with terrorism. Yet they find much to agree on once they focus on practical steps to improve both security and the environment, while keeping cost in mind. I might suggest, Mr. Chairman, that their spirit of practical cooperation could suggest some useful paths for us to pursue.

KURT M. CAMPBELL
EDITOR

# CLIMATIC CATACLYSM

## THE FOREIGN POLICY AND NATIONAL SECURITY IMPLICATIONS OF CLIMATE CHANGE

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1775 Massachusetts Avenue, N.W., Washington, D.C. 20036
www.brookings.edu



*Library of Congress Cataloging-in-Publication data*

Climatic cataclysm : the foreign policy and national security implications of climate change / Kurt M. Campbell, editor.
p. cm.
Summary: "Presents three scenarios of what the future may hold: expected, severe, and catastrophic and analyzes the security implications of each. Considers what can be learned from early civilizations confronted with natural disaster and asks what the largest emitters of greenhouse gases can do to reduce and manage future risks"—Provided by publisher.
Includes bibliographical references and index.
ISBN 978-0-8157-1332-6 (cloth : alk. paper)
1. Climatic changes—Government policy. 2. Climatic changes—Forecasting. 3. Climatic changes—Social aspects. 4. International relations—Forecasting. 5. National security.
I. Campbell, Kurt M. II. Title.
QC981.8.C5C625 2008
363.738'74526—dc22 2008012194

9 8 7 6 5 4 3 2 1

The paper used in this publication meets minimum requirements of the American National Standard for Information Sciences—Permanence of Paper for Printed Library Materials: ANSI Z39.48-1992.

Typeset in Minion

Composition by Circle Graphics
Columbia, Maryland

Printed by R. R. Donnelley
Harrisonburg, Virginia

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# A Partnership Deal: Malevolent and Malignant Threats

R. James Woolsey

> [There is] a tendency in our planning to confuse the unfamiliar with the improbable. The contingency we have not considered looks strange; what looks strange is therefore improbable; what seems improbable need not be considered seriously.
>
> —Thomas C. Schelling, foreword, *Pearl Harbor: Warning and Decision* (1962)

> Year after year the worriers and fretters would come to me with awful predictions of the outbreak of war. I denied it each time. I was only wrong twice.
>
> —Senior British intelligence official, retiring in 1950 after forty-seven years of service, quoted in Amory Lovins and Hunter Lovins, *Brittle Power: Energy Strategy for National Security*

The first two scenarios in this exercise dealt generally with climate change, the role of greenhouse gas emissions therein, and the regional consequences of smaller but substantial changes—up to a temperature rise of 2.6°C (4.7°F) and sea level rise of approximately half a meter (1.6 feet) in a thirty-year period. The third scenario discussed catastrophic change where aggregate global temperature increased by 5.6°C (10.1°F) by the end of the century, accompanied by a dramatic rise in global sea levels of 2 meters (6.6 feet) in the same time period. We might call climate change a "malignant," as distinct from a "malevolent," problem—a problem of the sort

Einstein once characterized as sophisticated (*raffiniert*) but, being derived from nature, not driven by an evil-intentioned (*boshaft*) adversary.

Sophisticated malignant problems can still be awesomely challenging. For example, because complex systems can magnify even minor disturbances in unpredictable ways—the so-called butterfly effect—a tree branch touching some power lines in Ohio during a storm can produce a grid collapse. In 2003 such a tree branch–power line connection deprived the northeastern United States and eastern Canada of electricity for some days. Similarly, our purchases today of gas-guzzling SUVs can contribute to sinking portions of Bangladesh and Florida beneath the waves some decades hence. With respect to climate change three factors should lead a prudent individual to consider such catastrophic change plausible: first, the possibility that some positive feedback loops could radically accelerate climate change well beyond what the climate models currently predict; second, the prospect of accelerated emissions of carbon dioxide ($CO_2$) in the near future due to substantial economic and population growth, particularly in developing countries such as China; and third, the interactive effects between these two phenomena and our increasingly integrated and fragile just-in-time—but certainly not just-in-case—globalized economy.

## Exponential Change and Scenario Planning

The possibility of catastrophic exponential change necessitates a unique approach. This is because few human beings naturally think in terms of the possibility of the exponential changes. We humans generally have what the inventor and futurist Ray Kurzweil calls an "intuitive linear" view of phenomena rather than a "historical exponential" view. In *The Singularity Is Near,* he uses the example of a property owner with a pond who frequently cleans out small numbers of lily pads. Then, with the pads covering only 1 percent of the pond, the owner goes away, but he returns weeks later to find it covered with lily pads and the fish dead.[1] The owner, because the human mind thinks linearly, forgot that lily pads reproduce exponentially. When change is exponential we often have great difficulty comprehending it, whether it is manifested in lily pad growth or climatological tipping points. A related difficulty is that the adaptability of human society itself is difficult to predict in the presence of great and continuing catastrophe. The conflicts over land, migrating populations, or resources described elsewhere in this study might well be overshadowed in such a case by broader societal collapse.

## Massively Destructive Terrorism

Another growing threat also holds out the possibility of massive damage and loss of life in this century: religiously rooted terrorism. The scope of death and destruction sought by the perpetrators of this sort of terrorism is also something most people find difficult to envision. This chapter later discusses terrorism (a "malevolent" rather than a "malignant" problem such as climate change) because of a somewhat surprising confluence: the aspects of our energy systems that help create the risk of climate change also create vulnerabilities that terrorists bent on massive destruction are likely to target. We need to be alert to the possibility that although our current circumstances are doubly dangerous, this confluence could give us an opportunity to design a set of changes in our energy systems that will help us deal with both problems.

## Positive Feedback Loops and Tipping Points

The climate models agreed upon by the Intergovernmental Panel on Climate Change (IPCC) deal with some, but by no means all, of the warming effects of emissions that can occur as a result of positive feedback loops. This is because climatologists, as scientists, are given to producing testable hypotheses and there are often not enough data to satisfy that requirement for a number of the feedback loop issues. But a number of climatologists have nevertheless assessed the data and offered judgments about the importance of possible feedback effects, even in this century. NASA's James Hansen puts it succinctly: "I'm a modeler, too, but I rate data higher than models."[2] Positive feedback loops can relatively quickly accelerate climate change to the tipping point, at which it becomes impossible to reverse destructive trends, even with future reductions of greenhouse gas emissions from human activities. Several such positive feedback loops are conceivable in this century, such as the risk that freshwater from melting Greenland glaciers would slow the North Atlantic meridional overturning circulation, changing ocean currents and attenuating the Gulf Stream's ability to warm Europe.

### *Polar Regions*

Tipping points at which there might be irreversible thawing of Arctic permafrost or the melting and breakup of the West Antarctic and the Greenland ice sheets have such stunning implications they deserve particular attention. Somewhere around a million square miles of northern tundra are underlain

by frozen permafrost containing about 950 billion tons of carbon—more than currently resides in the atmosphere.[3] If the permafrost were to thaw, much of this carbon would quickly convert to methane gas. At about one million tons annually, the increase in atmospheric methane content is much smaller than the increase in $CO_2$ content, which weighs in at about 15 billion tons per year.[4] However, a ton of methane affects climate twenty-five times more powerfully than a ton of $CO_2$ over a 100-year time horizon.[5] As a result, it would take only 600 million tons of methane to equal the global warming effect of 15 billion tons of $CO_2$. If this seems like an implausibly large increase in methane emissions, consider that it equates to only one-half of one-tenth of 1 percent of the organic carbon currently preserved in the permafrost (not to mention much larger amounts of frozen methane stored in shallow marine sediments). Therefore, if the permafrost begins to thaw quickly due to the initial linear warming trend we are experiencing today, the climate impact of methane emissions could come to rival that of $CO_2$ in future decades. Consequent accelerated warming and faster thaw leading to more methane emissions could produce a tipping point beyond which humans no longer control the addition of excess greenhouse gases to the atmosphere, and no options remain under our control for cooling the climate. We don't know the exact point at which this vicious circle would begin, but there are some indications that a substantial permafrost thaw is already under way.[6]

Because of methane's potency its release could provide a substantial short-term kick to climate change. Such release over a few decades could raise worldwide temperatures by 5 to 6°C (9 to 10.8°F) or more,[7] to the approximate level of temperature increase posited for the third scenario in this study. Another potential feedback loop lurks in the prospect of melting—and sliding—ice sheets in Greenland and West Antarctica. Around 125,000 years ago, at the warmest point between the last two ice ages, global sea level was 4 to 6 meters (about 13 to 20 feet) higher than it is today and global temperature was only about 1°C (1.8°F) higher.[8] Being warmer than Antarctica, Greenland probably provided the initial slug of meltwater to the ocean. However, much of the ice of western Antarctica rests on bedrock far below sea level, making it less stable as sea level rises.[9] When the ice sheet is lubricated by melting where it is grounded, it begins to float and can cause coastal ice shelves to shatter, increasing the rate of ice stream flow into the ocean (*ice stream* is a region of an ice sheet that moves significantly faster than the surrounding ice).[10] As a result of this action, the West Antarctic Ice Sheet contributed perhaps 2 meters (6 or 7 feet) of the additional sea level 125,000 years ago.

With just 1°C (1.8°F) of warming, therefore, we may be locked into about 4 to 6 meters (13 to 20 feet) of sea level rise.[11] James Hansen points out that

it is not irrational to worry about reaching this tipping point in this century. This study's catastrophic scenario assumes 5 to 6°C (9 to 10.8°F) of warming, which is significantly warmer than conditions 3 million years ago, before the ice ages. At that time, the Earth was 2 to 3°C (3.6 to 5.4°F) warmer and sea level was about 25 meters (82 feet) higher than today.[12] Although the time required for that much sea level rise to occur is probably more than 1,000 years, the third scenario, with 2 meters (6.6 feet) of sea level rise by the end of this century, appears quite plausible.[13]

### *Economic Development*

Robert Zubrin, the author of *Energy Victory: Winning the War on Terror by Breaking Free of Oil*, who is something of a climate change skeptic, suggests a simple thought experiment to illustrate the power of economic growth to affect climate change—a process that could create a climatic tipping point sooner rather than later. The world today has achieved an average GDP per capita comparable to U.S. GDP per capita at the beginning of the twentieth century (about $5,000 in today's dollars).[14] In the twentieth century, world population quadrupled and world economic growth averaged 3.6 percent annually.[15] Even if we assume slower population growth, say a doubling of world population in the twenty-first century, and also a lower growth rate of 2.4 percent—the latter producing a fivefold increase in GDP per capita—unless fuel use per unit of GDP changes substantially, we would see a tenfold increase in $CO_2$ emissions by century's end. This prospect leads even a climate change skeptic such as Zubrin to imagine an extraordinary scenario in which presumably all known and some unknown feedback loops become activated and thus it "only tak[es] a few decades to reach Eocene carbon dioxide atmospheric concentrations of 2,000 ppm"—and certain catastrophe.[16]

To take only one example of the impact of vigorous economic development on $CO_2$ emissions, China is building approximately one large coal-fired power plant per week for the foreseeable future. Rapidly growing developing countries are expected to account for an overwhelming 85 percent of energy-demand growth between 2008 and 2020. China alone represents a third of total growth.[17]

## Sea Level Rise and Challenges to Existing Infrastructure

The *2007 IPCC Working Group I Contribution to the Fourth Assessment Report* points out that the prospect of climate change and sea level rise coming to a tipping point is particularly troubling because once such a point has been passed, sea level rise will probably continue for centuries.[18] For this reason,

James Hansen considers sea level rise as "*the* big global issue" that will transcend all others in the coming century.[19] Even if the East Antarctic Ice Sheet is not destabilized, the steady melting of the Greenland Ice Sheet together with the perhaps sudden melting of the West Antarctic Ice Sheet holds the potential for some 12 meters (40 feet) of sea level rise.[20] The melting of the East Antarctic shelf would add approximately 25 meters (80 feet); this would mark, in the Antarctic research scholar Peter Barrett's words, "the end of civilization as we know it."[21] Even without a melting of the East Antarctic shelf, civilization would be experiencing an inexorable encroachment of seawater over decades and centuries.

Moreover, humanity would have to face the coastal inundation and related destruction while dealing with substantial disruption of agriculture and food supplies, and resulting economic deprivation, due to changing availability of water—some places more arid, some wetter—and a much smaller percentage of available water would be fresh.

### *Coastal Regions*

The catastrophic scenario outlined in chapter 6 listed among the regions in the developed world facing the likely prospect of inundation by the end of the century: major portions of cities and wide regions of the U.S. coast from South Texas to West Florida and from East Florida to New York; extensive areas bordering the Chesapeake Bay and most of South Florida and eastern North Carolina; the lower Hudson River Valley; huge shares of the coasts of San Francisco Bay; much of Sydney and all of Darwin, Australia; a large share of Japanese ports; Venice and a major share of coastal Tuscany; the majority of the Netherlands; much of Dublin; a major share of Copenhagen; and the Thames River Valley and the eastern and southern coasts of England.[22] Storm surges would affect people much farther inland and on more elevated coastlines.

Even without considering storm surge, sea level rise in the range of 2 meters (6.6 feet) in this century could have a potentially catastrophic effect on a number of developing countries. According to a February 2007 World Bank policy research working paper, these include particularly Egypt, Vietnam, and the Bahamas and a number of other island nations. It could also have "very large" effects on a number of other states, including China and India. Considering all factors—land area, urban area, population, and so forth—the most affected countries, in addition to those just cited, would be Guyana, Surinam, and Mauritania. Substantial impacts would also occur in Gambia, Liberia, Senegal, Guinea, Thailand, Burma, Indonesia, Taiwan, Bangladesh, and Sri Lanka.

A 2-meter (6.6-foot) rise in sea levels—together with changed climate, agricultural disruptions and famines, the spread of disease, water scarcity, and severe storm damage—will not occur in a world that is otherwise sustainable and resilient. Many areas are already destabilized. In the Philippines, for example, sea level rise would add to a problem already created by excessive groundwater extraction, which is lowering the land annually by fractions of an inch in some spots to more than a tenth of a meter (3 or 4 inches) annually.[23] The Mississippi Delta has a similar problem with land subsidence. Some of the land south of New Orleans will likely lose about 1 meter (3 feet) of elevation by the end of this century as a result of subsidence.[24] Thus, about 6 feet (about 2 meters) of sea level rise by the end of the century may well be additive to the substantial lowering of land levels in some areas by such groundwater extraction. And the concentration of population in low-lying areas of course exacerbates the effect of these changes.

Meltwater runoff from mountain glaciers also supplies agricultural and drinking water as well as electricity from hydropower. More than 100 million people in South America and 1 billion to 2 billion in Asia rely on glacial runoff for all or part of their freshwater supply. As these glaciers shrink and produce less meltwater they will contribute substantially to the need to emigrate in search of water and arable land. The relevant glaciers are retreating rapidly and some are already virtually gone. This problem is likely to peak within mere decades.[25]

## Potential National Security Consequences of Climate Change

In a world that sees a 2-meter (6.6-foot) sea level rise with continued flooding ahead, it will take extraordinary effort for the United States, or indeed any country, to look beyond its own salvation. All of the ways in which human beings have responded to natural disasters in the past, which John R. McNeill describes in chapter 2, could come together in one conflagration: rage at government's inability to deal with the abrupt and unpredictable crises; religious fervor and perhaps even a dramatic rise in millennial end-of-days cults; hostility and violence toward migrants and minority groups, at a time of demographic change and increased global migration; and intra- and interstate conflict over resources, particularly food and freshwater.

Altruism and generosity would likely be blunted. In a world with millions of people migrating out of coastal areas and ports across the globe, it will be extremely difficult, perhaps impossible, for the United States to replicate the kind of professional and generous assistance provided to Indonesia

following the 2004 tsunami. Even overseas deployments in response to clear military needs may prove very difficult. Nuclear-powered aircraft carriers and submarines might be able to deploy, but aviation fuel or fuel for destroyers and other non-nuclear ships could be unobtainable. Overseas air bases would doubtless be tangled in climatic chaos, and aircraft fuel availability overseas highly uncertain. Further, the Navy is likely to be principally involved in finding ways to base, operate, overhaul, and construct ships, as many ports and harbors south of New York on the East Coast and overseas disappear or become usable only with massive expenditures for protection from the rise in sea levels. Civilians will likely flee coastal regions around the world, including in the United States. The U.S. military's worldwide reach could be reduced substantially by logistics and the demand of missions near our shores.

### *Population Changes and Migrations*

If Americans have difficulty reaching a reasonable compromise on immigration legislation today, consider what such a debate would be like if we were struggling to resettle millions of our own citizens—driven by high water from the Gulf of Mexico, South Florida, and much of the East Coast reaching nearly to New England—even as we witnessed the northward migration of large populations from Latin America and the Caribbean. Such migration will likely be one of the Western Hemisphere's early social consequences of climate change and sea level rise of these orders of magnitude. Issues deriving from inundation of a large portion of our own territory, together with migration toward our borders by millions of our hungry and thirsty southern neighbors, are likely to dominate U.S. security and humanitarian concerns. Globally as well, populations will migrate from increasingly hot and dry climates to more temperate ones.

On the other hand, extrapolating from current demographic trends, we estimate that there will be fewer than 100 million Russians by 2050, nearly a third of whom will be Muslims. Even a Europe made colder by the degrading of the Gulf Stream may experience substantially increased levels of immigration from south of the Mediterranean, both from sub-Saharan Africa and from the Arab world. Many of Europe's Muslim minorities, including Russia's, are not well assimilated today, and the stress of major climate change and sea level rise may well foster social disruption and radicalization. Russia and Europe may be destabilized, shifting the global balance of power.

Northern Eurasian stability could also be substantially affected by China's need to resettle many tens, even hundreds, of millions from its flooding southern coasts. China has never recognized many of the Czarist appropria-

tions of north Central Asia, and Siberia may be more agriculturally productive after a 5 to 6°C (9 to 10.8°F) rise in temperatures, adding another attractive feature to a region rich in oil, gas, and minerals. A small Russian population might have substantial difficulty preventing China from asserting control over much of Siberia and the Russian Far East. The probability of conflict between two destabilized nuclear powers would seem high.

### *Energy Infrastructure*

Interactions between climate change and the existing infrastructure could create major failures in the systems that support modern civilization. All other systems—from operating telecommunications to distributing food, pumping water, and more—depend on energy. Yet energy systems themselves are vulnerable. Hydroelectric electricity generation may be substantially affected by reduced glacial runoff or by upstream nations diverting rivers in some parts of the world. Nuclear power plant cooling may be limited by reduced water availability. Increased numbers and intensity of storms could interfere with long-distance electricity transmission, already heavily stressed in the United States and elsewhere.

Sea level rise and chaotic weather patterns may interfere with oil production in a number of locations, particularly from sea-based platforms and in parts of the Middle East, and with the operation of large oil tankers. Many U.S. oil refineries are in the Gulf Coast region and thus more vulnerable to disruption by storms than if they were located elsewhere. Hurricane Katrina came very close to shutting down the Colonial Pipeline, the major link from the Gulf Coast to the Eastern Seaboard. In short, the pressures on U.S. society and the world would be significant, and the international community's ability to relieve those pressures seriously compromised. The abrupt, unpredictable, and relentless nature of the challenges will likely produce a pervasive sense of hopelessness.

## A Malevolent Threat: Mass Terrorism

Our society, our way of life, and our liberty face serious current challenges beyond the infrastructure fragility exacerbated by climate change. The most salient is attack by terrorist groups or an enemy state, or a combination thereof, aimed at massive damage and massive casualties. These are not unintentional "malignant" results of our habitual behavior but are rather "malevolent" and planned carefully by those who want to do far more than many terrorist groups in the past: namely, to destroy our entire civilization and way of life.

Oil presents a panoply of opportunities for highly destructive terrorism. Our transportation is fueled over 96 percent by petroleum products. Consequently oil has a transportation monopoly in much the same way that, until around the end of the nineteenth century, salt had a monopoly on the preservation of meat. Oil's monopoly creates a litany of vulnerabilities for our society.

Since around two-thirds of the world's proven reserves of conventionally produced oil are in the Persian Gulf region, together with much of oil's international infrastructure, the world's supplies are vulnerable to terrorist attacks such as two already attempted by al Qaeda in Saudi Arabia and emphasized in al Qaeda's doctrine. Some oil states' governments (Iran) are quite hostile today; others (Saudi Arabia) could become so with a change of ruler. A nuclear arms race appears to be beginning between Iran and six Sunni states that have announced nuclear programs "for electricity generation." The United States borrows more than a billion dollars a day at today's prices to import oil, substantially weakening the dollar. The Wahhabi sect of Saudi Arabia profits massively from oil income and, according to Lawrence Wright in *The Looming Tower: Al-Qaeda and the Road to 9/11,* covers "90 percent of the expenses of the entire faith, overriding other traditions of Islam."[26] Wahhabi teachings are murderous with respect to Shi'ite Muslims, Jews, homosexuals, and apostates; are hideously repressive of women; and are mirrored by the views of al Qaeda and similar groups except with respect to their allegiance to the Saudi state. And finally, as Bernard Lewis puts it, "There should be no taxation without representation but it should also be noted that there is no representation without taxation." Extremely wealthy oil-exporting states are thus often dictatorships and autocratic kingdoms without institutions that check and balance the ruler.

The other major energy sector of our economy, electricity generation and distribution, is also highly vulnerable to attack by terrorists and rogue states. In 2002 the National Research Council published its report on the use of science and technology to combat terrorism. It stated: "The most insidious and economically harmful attack would be one that exploits the vulnerabilities of an integrated electric power grid. 'A chain is only as strong as its weakest link' applies here. Simultaneous attacks on a few critical components of the grid could result in a widespread and extended blackout. Conceivably, they could also cause the grid to collapse, with cascading failures in equipment far from the attacks, leading to an even larger long-term blackout."[27]

As of 2008 very little has been done to implement the council's seventeen detailed recommendations to deal with this, particularly with regard to

improving the security of, or even stockpiling spares for, the large transformers at grid substations or effectively protecting the grid's Supervisory Control and Data Acquisition (SCADA) control systems from destructive hacking. Additionally, the electricity grid has a major vulnerability to an electromagnetic pulse (EMP). In 1962 both Soviet and American atmospheric nuclear tests revealed a troubling phenomenon: three types of electromagnetic pulses generated at high altitude by nuclear detonations could seriously damage or destroy electronic and electrical systems at as much as 1,610 kilometers (1,000 miles) from the blast. The 2004 report of the U.S. Electromagnetic Pulse Commission pointed out that the detonation of a single nuclear warhead between 40 and 400 kilometers (25 and 250 miles) above the Earth could cause "unprecedented cascading failures of our major infrastructures," primarily "through our electric power infrastructure" crippling "telecommunications . . . the financial system . . . means of getting food, water, and medical care to the citizenry . . . trade . . . and production of goods and services." The commission noted that states such as North Korea and Iran, possibly working through terrorist groups, might not be deterred from attack (say using a relatively small ship carrying a simple SCUD missile) in the same way as were our adversaries in the cold war.[28]

The commission concluded that detonation of a single nuclear warhead at these altitudes could "encompass and degrade at least 70 percent of the Nation's electrical service, all in one instant." It also notes that, as a result of fire safety and environmental concerns, locally stored fuel for emergency power supplies such as diesel for generators is often limited to about a seventy-two hours' supply.[29] Food available in supermarkets generally supplies about one to three days of requirements for customers, and regional food warehouses usually stock enough for a multicounty area to last about one month.[30]

## Toward a Partnership to Deal with Both Malignant and Malevolent Threats

These malignant and malevolent risks seem to stem from very different causes—and different kinds of people, with different backgrounds, tend to look at them separately. This cultural separation—analogous in some ways to C. P. Snow's famous description some decades ago of the intellectual world's division into the two cultures of literature and science—hinders cooperative action. For the issues at hand, let's call this a division between the tree-hugger culture, focused on carbon, and the hawk culture, focused on terrorism.

Both the malignant and malevolent problems described here are extraordinarily grave, and much too urgent to await a lengthy debate between the two cultures about how intensely we should believe that each risk will become manifest. This is especially true because, as suggested below, the steps needed to contend successfully against both types of problems appear to have a great deal in common, at least in the important field of energy.

A hawk who is steeped in the history of the Muslim Brotherhood but has no time for the history of glaciers need not be required to pledge his belief that climate change will hit a certain degree by a certain date. Scientific theories, Karl Popper taught us, must always be held tentatively; they are productive precisely to the degree that they offer an invitation to be *dis*proved. Even as society used Newton's theories for centuries, the path of human progress was to give others a chance to create theories that would replace his. Eventually Einstein's did.

Nevertheless, we should argue to our hawk that as a matter of judgment, not certainty, there is sufficient evidence of developing climate change that he or she should take the issue seriously. Further, if we consider together plausible climatic tipping points and the increased emissions from world economic development, there is a risk that such change could become cataclysmic. Thus, the only responsible course of action is to begin now to deal with the problem as sensibly and affordably as we can.

We should say something similar to a tree hugger who is quite attentive to possible change in the North Atlantic meridional overturning circulation but who believes that to deal with terrorism now and for the foreseeable future we need only enforce the criminal law—and that a rogue state or terrorist EMP attack on the United States must be someone's idea of a film plot for the PG-13 market. The tree hugger's blind spot is precisely where the hawk's eyes are trained, and vice versa. But our tree hugger needs to remember that fanatic enemies with access to destructive technology have already wreaked mass death on modern societies. The tree hugger needs to keep an open mind, remember the Nazis, and recognize that evil exists, and happens.

As a thought experiment we might try inviting a tree hugger, someone strongly committed to reducing the risk of climate change, to address a major malignant issue by producing a short list of policies that could soon lead to substantial reductions of emissions. We will ask the tree hugger to focus on the ways in which we generate electricity, fuel transportation, power industry, and operate buildings, leaving such topics as preventing

deforestation and promoting proper agricultural practices until later. We want him to focus on energy because we are going to submit his list to someone else for comment—a hawk who is heavily focused on energy security—to see if there is anything on which they can agree.

For our tree hugger we decide to summon the shade of John Muir, the father of our national parks system and the first president of the Sierra Club, and for our hawk, the shade of George S. Patton, commander of the Third Army in World War II. They eye each other warily, but agree to undertake our project.

After sitting and pondering thoughtfully for a time under some redwoods, Muir submits a list of nine proposals for Patton's consideration:

*1. Begin with improving the energy efficiency of buildings.*

Muir notes that Wal-Mart is finding that with such simple steps as painting its store roofs white and adding skylights, the company is getting 20 percent improvement in energy efficiency today and expects 25 to 30 percent improvements by 2009. And Muir has seen a recent McKinsey & Company report that says that merely by using existing technologies (where there is an internal rate of return of 10 percent or more) we can reduce world energy demand by 125 to 145 QBTUs (quadrillion British thermal units) by 2020, 20 to 24 percent of end-use demand. The vast majority of this, the report says, would be in buildings of all sorts, including industrial facilities, and would contribute up to half the greenhouse gas emission abatement needed to cap the long-term concentration of greenhouse gases in the atmosphere at 450 to 550 ppm.[31] Muir knows that the Rocky Mountain Institute's thorough work shows even more opportunity for energy savings from reduced energy use in buildings.[32]

"I'm completely with you on this one," says Patton. "Less need for energy, less need to add generating capacity and transmission lines to the grid. Every day, the grid reminds me more and more of the Maginot Line, just sitting there vulnerable to being taken out by creative tactics—the less we need it the better. And I like the fact that this efficiency stuff makes money for the folks who implement it rather than costing something."

*2. Radically increase the use of combined heat and power (CHP).*

His second item, Muir says, could be implemented relatively quickly and would let us get dual use from energy instead of wasting a lot of the heat our industry produces by just venting it into the atmosphere. About a third of Denmark's electricity, for example, comes from CHP. Only about 8 percent of

U.S. electricity comes from CHP, but the problem—like building efficiency—is not that we don't have the technology. Rather, Muir says, our commitment to wasting heat is determined by culture and regulations. Much of the reason CHP struggles in the United States is because of the opposition of state public utility commissions (PUCs). Certain steps are needed to ensure safety, Muir concedes, but the Danes have figured this out and completely changed their system in just twenty years. To do what they've done we just need to change most states' PUC policies. CHP generally has the effect of generating electricity and heat closer to where they are used, in relatively small facilities, Muir notes.

"Go, Danes!" says Patton. "You know, John," he continues, "I admit I was pretty skeptical when I agreed to do this with you, but I've gotta admit I'm learning some things and I like this one, too. Just using energy we're already producing—makes all the sense in the world. And it looks like each of these two ideas of yours reduces the need for new centralized power generation plants as well as new long-distance transmission lines. Relying on smaller, more distributed, production should improve resilience against terrorist attack. Keep 'em coming."

*3. Create strong long-term incentives for small-scale (single-building-based) distributed generation of electricity and heating and cooling.*

Forty out of fifty states, Muir says, now have "net metering" laws that in principle make it possible for those who have generating capacity—say roof-top solar photovoltaic systems—to sell some home-generated electric power back to the grid. But in practical terms, state laws and regulations leave a lot to be desired in making this work. The cost of home-generated power is about to decline sharply, says Muir. As thin-film and nano-solar technologies come on the market at costs substantially below those of today's silicon cells, and as solar collectors are integrated into building materials such as shingles, these technologies can begin to have a substantial effect on the need for central power generation. Small-scale wind turbines, operating at lower wind speeds than the large wind turbines, are beginning to come into the single-building market as well. Distributed solar and wind technologies complement one another, since generally the sun shines at a different time of day than the wind blows, and increased use of both can be facilitated by storing electricity in improving batteries. Shallow (heat pump) geothermal is showing promise for heating and cooling of individual buildings; together with distributed solar and wind it may be able to satisfy a very substantial share of individual building energy needs. Distributed generation will be renewable

and hence not carbon-emitting, Muir notes: a coal-fired power plant will not fit on a roof.

"John," says Patton, "anyone who has ever been in combat knows that you need flexibility and initiative at the small-unit level because the unexpected always happens, and if your small units are good you can adapt faster. I've always said, "Small had damned well better be beautiful." You have to be able to put maximum reliance on your platoon leaders and sergeants—that's how I was able to relieve Bastogne so fast. You're making me see that the same logic applies to having an energy system that's resilient against terrorist and EMP attack. Damn, are you sure you don't have a military background?"

*4. Follow California's lead and decouple sales from earnings for electric utilities to encourage conservation and grid modernization.*

This is a big one, says Muir. California, he notes, initiated this simple step some twenty years ago; there, and (very recently) in several other states, utilities' earnings are based on their investment, not their sales of electricity. But in the other forty-plus states, utilities must sell more electricity in order to earn more for their shareholders. It doesn't matter if it's used wastefully—the incentive systems established by forty-some PUCs don't deter waste. In California and the other few states, though, if a utility invests in making the grid "smarter," say, to help consumers conserve electricity, it earns more for its shareholders. The effect of decoupling sales from earnings is dramatic: over the last twenty years, electricity use per capita in California has stayed flat, while that of the rest of the country has increased 60 percent. Major double-digit improvements in energy efficiency are possible if the other approximately forty PUCs would just admit that what a few states have done is problem-solving and that their own current policies are problem-creating.

"Sounds great," says Patton. "I know California screwed up on the Enron thing a while back—hell, everybody screws up sometimes—even I did once. But the Californians sure have this decoupling right. Say, who writes those other forty PUCs' fitness reports? Why don't their superior officers just relieve them of command and put somebody in charge who's willing to learn from what the California folks have done?"

*5. Give steady and long-term encouragement to the deployment of renewable electricity generation for the grid from wind, solar, hydro, and geothermal.*

Muir tells Patton that many incentives such as tax credits for such deployment have been periodically interrupted, delaying, for example, production of wind turbines and slowing the introduction of these technologies.

"Well," says Patton, "if we have to add to the grid I suppose these are okay. The grid will be around for a long time, so we have to improve its resilience by stockpiling transformers and defending better against cyber attacks in any case. But even if we improve its defenses and make it cleaner, increasing our reliance on a Maginot Line is not my favorite way to go. I liked your efficiency and CHP and rooftop ideas better, but I guess I can go along with these—I like the fact that at least some of them probably won't be too large and can be distributed to some extent. Also, power plants using sun, wind, hydro and geothermal aren't vulnerable to terrorist interruption of their fuel supplies."

*6. Vigorously develop carbon capture and storage (CCS) for coal-fired power plants.*

Muir points out that this may well rely on the already-developed technology of integrated gasification combined cycle (IGCC) plants, which facilitates $CO_2$ capture. The hard part is sequestering the $CO_2$ permanently where it will not leak into the atmosphere. The $CO_2$ gas may be pumped into existing oil and gas wells to enhance recovery from them. Pumping it into salt-water aquifers deep beneath the earth also shows promise for long-term sequestration.

Again, Patton is only lukewarm. "Adding to the grid just gives the terrorists eyeing our transformers and the crazy guys with EMP attack plans a bigger target," he says. "But if we can't get all the power we need by implementing your ideas about reducing demand and increasing distributed generation, then I'm okay with this CCS stuff, but reluctantly."

*7. Provide tax incentives for the purchase of plug-in hybrid gasoline-electric vehicles (PHEVs).* Now for transportation, Muir says. GM has announced the production of the Chevrolet Volt plug-in hybrid (PHEV) in 2010 (they call it an "electric vehicle with range extension"); Toyota's Prius was designed originally with an all-electric mode for driving, so it is well on the way to being a plug-in once a battery more capable than that in the current Prius is supplied. Other manufacturers are gearing up to produce plug-ins as well. There are dozens of hybrid vehicles, principally Priuses, that their owners have converted into PHEVs using currently available batteries. A PHEV that is plugged into a standard 120-volt socket in a garage overnight can be driven 32 to 65 kilometers (20 to 40 miles) the next day on this charge. Once it reaches the end of the electricity supplied in its overnight charge it becomes an ordinary hybrid, using both gasoline and electricity until it can be charged again. These

vehicles seem to be getting over 160 kpg (100 mpg) once their initial all-electric driving is factored in. (Muir suggests to Patton he take a look at the websites pluginamerica.com and calcars.org.

The average U.S. light vehicle is driven just over thirty miles a day, Muir adds. It is clear that, in addition to providing consumers the ability to drive for some tens of miles a day on inexpensive off-peak overnight electricity at a fraction of the cost of driving on gasoline, moving from a standard internal-combustion-engine vehicle to a PHEV reduces greenhouse gas emissions substantially. A recent Pacific Northwest National Laboratory study has estimated that if 73 percent of the current U.S. fleet of light-duty vehicles were converted to PHEVs that were able to drive just over thirty miles all-electrically and were charged during off-peak hours, no new power plants would be needed. Moreover this would displace 6.5 million barrels of oil equivalent per day, or approximately 52 percent of the nation's oil imports. The average reduction nationally of greenhouse gases would be in the range of 27 percent per car, more in states using little coal to produce electricity, around zero in heavy coal-using states.[33] And over time cleaning up the grid also cleans up PHEV emissions: as electricity production is modified—say, via renewables or coal with carbon capture and sequestration—$CO_2$ emissions are further reduced.

Finally, PHEVs can replace certain "ancillary services" that cost about $12 billion annually, such as fossil fuel purchases to stabilize and regulate the grid's operations and "spinning" reserves to deal with power outages. Keeping just a small number of PHEVs plugged into the grid after they are charged creates vehicle-to-grid (V2G) connections that replace fuel-consuming functions.[34] This can mean a lot less use of fossil fuel and also substantial payments back to plug-in hybrid owners. One Federal Energy Regulatory Commission member even calls plug-ins "cash-back hybrids." Grid modernization can help implement such major innovations.

"John, now you're talking again," says Patton. "Electricity (and plug-ins) can do to oil what electricity (and refrigeration) did to salt around the time I was born—destroy the damned stuff as a strategic commodity. Salt used to be a really big deal because it was the only way to preserve meat. People even fought wars over it. But now nobody gives a damn what country has salt mines. Since around the time I commanded the Third Army, maybe before, the number one strategic commodity has been oil. It sure was in the war. If old Tooey Spaatz, God bless him, hadn't persuaded FDR to let him hit Ploesti and Leuna and take out the Germans' fuel, they would have had enough for the Panzers to get to Antwerp and the Battle of the Bulge could have gone the other way."

Patton shakes his head sadly. "You know, John, there are some jaspers at the Council on Foreign something-or-other in New York who say we're doing a 'disservice to the nation' by trying to get the country away from oil dependence. Do they think it's a 'service' to make it easier for some other country to have the leverage over us that we had over the Germans in the war? Those guys would probably also tell drunkards to make sure they have a glass or two of red wine every day for their health—not crazy in the abstract, but sure as hell not the message a guy in his cups needs to hear. But you're telling those council guys to get with the program and help get us off oil fast—John, you're my man."

*8. Mandate a rapid transition to flexible fuel vehicles (FFVs).*
Muir says this is simple, and would mean that both U.S.-produced vehicles and imports could use at least gasoline, ethanol (particularly cellulosic), butanol, and methanol in any mixture. This would create a market for renewable fuels by removing a needless barrier, Muir points out. He adds that using such fuels can substantially reduce greenhouse gas emissions, especially when the feedstocks are biomass and waste. The cost is modest—around $100 per vehicle or less. Between 2002 and 2005, Brazil moved from 5 percent to 75 percent of their new vehicles' being FFVs. Incentives such as tax credits should be provided promptly to encourage pumps for these fuels to be installed at stations.

"Hey, John," Patton booms. "I'm fine with markets and cap-and-trade and all that, but sometimes ya gotta just tell people to, damn it, *do* it. I got no problem with mandates—hell, if you gotta move fast and it's important, I absolutely *love* 'em. We did it for cars with seat belts and air bags because people's lives were at stake. Well, they're at stake because of oil dependence too. Getting away from that dependence is a matter of national security. Somebody just needs to show as much gumption as the Brazilians and issue a damned *order* about obvious stuff like this."

*9. Provide incentives for the production of renewable fuels and specialty chemicals from cellulosic biomass; give special attention to the desirability of using waste products as a feedstock, particularly where methane is thereby reduced.*
Muir points out that we should be moving away from hydrocarbons and toward carbohydrates generally as feedstocks for liquid fuels, electricity generation, and chemical production. But he is especially worried about a number of wastes producing methane if left in their natural state because of the latter's potency as a greenhouse gas—more than twenty times that of $CO_2$.

"Fine with me, John," says Patton. "Let's clean stuff up while we get off oil—a threefer: helps thwart the terrorists, reduces that carbon you're so worried about, and things smell better. I'm gonna start calling you 'God's janitor.' Basically you're nine for nine. Pretty interesting—we keep getting to the same place as long as we don't have to agree with one another's reasons for going there. Who'da thought it?"

"But there are three things you didn't mention," he adds: "Nuclear power, hydrogen, and coal-to-liquid transportation fuels. I've seen a lot of guys lobbying lately on all three of those—must be some money behind 'em. What do you think?"

Patton and Muir talk for a while and agree that nuclear power plants may be an acceptable last resort if we have to add generating capacity in the United States. Muir winces at the prospect, but in spite of the waste storage problem he's always been worried about, he's come reluctantly to support nuclear in some cases because of nuclear plants' lack of carbon emissions. Patton has a nagging problem with terrorist threats to power plants, but agrees that it would be very hard to cause a core meltdown. The two agree we should definitely oppose spreading nuclear energy around the world to new countries, since with today's treaties and inspections it's impossible in practical terms to stop countries from using their nuclear "electricity" programs as a way to get into the nuclear weapons business.

The hydrogen discussion just takes a few seconds. Both see some uses for hydrogen, but when they start talking about driving the "hydrogen highway" in family cars with hydrogen fuel cells and hydrogen storage and pumps at neighborhood filling stations, they shake their heads, amazed at the cost—especially, they chuckle, since the only infrastructure fueling cost you need for plug-in hybrids is an extension cord for each car-driving household.

Coal-to-liquids (CTL) is their only area of disagreement. Muir hates the carbon it would produce; Patton likes the way it undermines oil. As they finish their discussion, Patton puts a hand on Muir's shoulder and says, "John, tell you what I'll do. Even though CTL plants would use American coal, which I like, some plants might need a big infrastructure that could be vulnerable to terrorists, which I don't like. I'm happy with your transportation ideas because they move us toward small local plants and distributed production of fuel, whether electricity or liquid—nicely resilient. How about this: unless they figure out how to sequester enough of the carbon from CTL to satisfy you, I won't drop this option but I'll move it down to the bottom of my list—but in exchange I'd like a little help from you on

another matter: I think the Army needs at least two to three more armored divisions. What do you say?"

"George," laughs Muir, "You're a piece of work. I might be able to talk myself into rolling over for one or two of those things, but, if I do, for each one I support I'm going to need your backing for at least one new national park."

"John," says Patton, "I like your style. Say, can you hunt in those places?"

"George," gasps Muir, "you are absolutely imposs—"

Patton grins. "Just pullin' your chain."

As they stroll off together into the evening haze, Patton's ghost begins slightly to resemble Humphrey Bogart, and Muir's, Claude Raines. Patton grins and says, "Y'know, Johnny, this could be the start of a beautiful friendship."

## Notes

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Mr. MARKEY. Thank you, Mr. Woolsey, very, very much.

Our next witness is Dr. Kristie Ebi, an independent consultant specializing in impacts of and adaptation to climate change. She is a lead author of both the human health chapter of the United Nations' Intergovernmental Panel on Climate Change's Fourth Assessment Report and for the United States Climate Change Science Program's Synthesis Assessment Product on the effects of the global change on human health and welfare and human systems. We thank you, Dr. Ebi, for being here. Whenever you are comfortable, please begin.

**STATEMENT OF KRISTIE L. EBI, PUBLIC HEALTH CONSULTANT, LEAD AUTHOR, PUBLIC HEALTH CHAPTER OF THE 2007 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, FOURTH ASSESSMENT REPORT**

Ms. EBI. Thank you very, Mr. Chairman. I appreciate the opportunity to talk with all the members here on the Subcommittee on Energy and the Environment.

Climate change poses current and future risks for U.S. citizens. Although data are limited, injuries, illnesses, and death due to climate change may already be occurring with the magnitude and extent of adverse health impacts expected to increase with additional climate change. The risks include greater numbers of preventable illnesses and deaths due to increases in the frequency, intensity, and length of heat waves with the greatest risk among older adults, those with chronic medical conditions, infants, children, pregnant women, outdoor workers, and the poor. Climate change is projected to increase heat-related mortality several fold, increases in the frequency and intensity of floods, droughts, wildfires, and windstorms with the risk highest among the poor, pregnant women, those with chronic medical conditions and those with mobility and cognitive constraints. Projecting additional health burdens is difficult because extreme weather events, by definition, are rare. However, the impacts can be large for single events, higher concentrations of ground-level ozone with the highest risk among asthmatics and those with chronic heart or lung disease, diabetics, athletes, and outdoor workers.

Without taking into account possible changes in the precursors required for ozone formation, ozone-related morality is projected to increase at least 4 percent by 2050 in the New York area alone. Ozone-related morbidity also would be expected to increase, including more asthma attacks among susceptible individuals. Certain food- and waterborne diseases with the highest risks among older adults, infants, and those who are immunocompromised. The number of cases of salmonella, which has caused several recent foodborne outbreaks, increases with ambient temperature. Possible changes in the geographic range and incidence of waterborne and zoonotic diseases. Reports are appearing of infectious disease outbreaks in areas that previously have been considered too cold for their transmission.

Other health impacts also may increase. For example, there are anecdotal reports of increases in suicide rates among native Alaskans associated with the loss of culture, lands, and livelihoods because of melting permafrost, loss of sea ice, and other changes due

to climate change. The magnitude and extent of these impacts will vary significantly across regions, requiring understanding of the local factors that interact with climate change to increase the health risks. Demographic trends such as an older and larger U.S. population will increase overall vulnerability. In addition, the United States may be at risk from climate-related diseases and disasters that occur outside our borders. The unprecedented nature of climate change may bring unanticipated consequences for public health. The current and projected health impacts of climate change are significantly larger in low-income countries, challenging their ability to achieve the millennium development goals.

Adaptation and mitigation are equally important for addressing these health risks. Neither is sufficient. Focusing only on mitigation will leave communities inadequately prepared for the changes expected in the short term and focusing only on adaptation will increase the amount of future climate change to which communities will need to adapt. The United States has well-developed public health infrastructure and environmental regulatory programs that if maintained would moderate the risks of climate change. However, there are limits to the degree to which adaptation can reduce these health impacts. Some low-income countries are struggling to adapt to the climate change impacts they are experiencing now. As we heard, that does increase our national security threats.

Actions that lead to greenhouse gas emissions reductions can have significant positive impacts on human health. For example, in the year 2020, thousands of premature deaths and tens of thousands of asthma-related emergency room visits could be prevented from the implementation of a range of activities that reduce fine particulate matter concentrations associated with carbon dioxide emissions. In addition to saving lives, the associated economic benefits would range from $6 billion to $14 billion, and that is in 1 year.

Thank you very much.

[The prepared statement of Ms. Ebi follows:]

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Before the
U.S. House of Representatives
Sub-Committee on Energy and Environment
Committee on Energy and Commerce
"The Climate Crisis: National Security, Public Health, and Economic Threats"

10:00 a.m., February 12, 2009
Room 2123, Rayburn House Office Building

**Summary**

Climate change poses health risks for U.S. populations, both direct impacts on health as well as through altering the systems on which human health and well-being depend. Although data in the U.S. are limited, health impacts due to climate change may already by occurring, with the magnitude and extent of impacts expected to increase with increasing climate change. The health risks of current and future climate change in the U.S. include greater numbers of illnesses and deaths due to (Ebi et al. 2008):

- Increases in the frequency, intensity, and length of heatwaves, with the highest risks among older adults, those with chronic medical conditions, infants and children, pregnant women, urban and rural poor, and outdoor workers. With limited mitigation or adaptation, heat-related mortality is projected to increase several-fold.
- Increases in the frequency and intensity of other extreme weather events, including floods, droughts, wildfires, and windstorms, with the risks highest among the poor, pregnant women, those with chronic medical conditions, and those with mobility and cognitive constraints. Projecting additional health burdens is difficult because these events are, by definition, rare. However, the impacts can be large for single events.
- Higher concentrations of ground-level ozone, with the highest risks among asthmatics and those with chronic heart or lung diseases, diabetics, athletes, and outdoor workers. Without taking into account possible changes in the precursors that are required for ozone formation, ozone-related mortality is projected to increase 4% by 2050 in the New York area. Ozone-related morbidity also would be expected to increase, including more asthma attacks in susceptible individuals.
- Certain diarrheal diseases, with the highest risks among older adults, infants, and those who are immunocompromised. Several studies have found that the number of reports of cases of salmonella, which has caused several recent foodborne outbreaks in the U.S., increases with increasing temperature.
- Possible changes in the geographic range and incidence of vectorborne and zoonotic diseases. There are several reports of infectious diseases appearing in areas that had previously been considered too cold for their transmission.
- Other health impacts also may increase. For example, there are anecdotal reports of increases in suicide rates among Native Alaskans associated with the loss of lands and livelihoods because of melting permafrost, loss of sea ice, and other changes due to climate change.

Demographic trends, such as a larger and older U.S. population, will increase overall vulnerability to these health risks. In addition, the U.S. population may be at risk from climate-related diseases and disasters that occur outside U.S. borders, with travelers and refugees importing diseases not currently present. The unprecedented nature of climate change also may bring unanticipated consequences for public health.

The magnitude and extent of these impacts will vary significantly across regions, requiring understanding of the local factors that interact with climate change to increase

the health risks. Adaptation and mitigation are equally important for addressing these risks. Neither is sufficient in itself; focusing only on mitigation would leave communities inadequately prepared for changes expected in the short term, and focusing only on adaptation would increase the amount of future climate change to which communities would need to adapt. There will be limits to the degree to which adaptation can reduce health burdens due to climate change.

In addition to increasing the public health capacity to prepare for and effectively respond to climate change, there is an urgent need to evaluate the possible health consequences of policies and technologies being developed to reduce emissions of greenhouse gases, from energy efficiency policies to carbon capture and storage. Responses to climate change may alter energy, transportation, and other systems required for our societies to function; health risks may arise from changes in any of these systems. Better understanding is needed of how these systems interact with health, including risks and opportunities for interventions to improve population health.

## 1.0 The Potential Health Impacts of Climate Change

The observation that major causes of ill health exhibit distinct seasonal patterns suggests *a priori* that weather and/or climate influence their distribution and incidence. Weather, climate variability, and climate change affect a wide range of health outcomes directly and indirectly. Directly, heatwaves, floods, droughts, windstorms, and fires annually affect millions of people and cause billions of dollars of damage. In 2003 in Europe, Canada, and the United States, floods and storms resulted in 101 people dead or missing and caused $9.73 billion in insured damages (Swiss Re 2004). More than 35,000 excess deaths were attributed to the extended heatwave in Europe the same year (Kostasky 2005). The frequency and intensity of extreme weather events are expected to increase over the coming decades as a consequence of climate change, suggesting that the associated health impacts also could increase.

Indirectly, climate can affect health through alterations in the geographic range and intensity of transmission of vector-, tick-, and rodent-borne diseases, and food- and waterborne diseases, as well as through changes in the prevalence of diseases associated with air pollutants and aeroallergens. Climate change could alter or disrupt natural systems, making it possible for diseases to spread or emerge in areas where they had been limited or had not existed, or for diseases to disappear by making areas less hospitable to the vector or the pathogen (NRC 2001). Climate-induced economic dislocation and environmental decline also can affect population health.

The cause-and-effect chain from climate change to changing patterns of health determinants and outcomes is often complex and includes factors such as wealth, distribution of income, status of the public health infrastructure, provision of medical care, and access to adequate nutrition. Therefore, the severity of future impacts will be determined by changes in climate as well as by concurrent changes in non-climatic factors and by policies implemented to reduce negative impacts. It is important to note that even if total burdens of some climate-sensitive health outcomes decrease in the future, the attributable burden due to climate change is projected to increase.

The capacity of the U.S to develop and deploy effective and timely policies to address climate change is assumed to remain high throughout this century, thus reducing the likelihood of severe health impacts if appropriate programs and activities are implemented. However, the nature of the risks posed by climate change means that some adverse health outcomes may not be avoidable.

***Extreme Weather Events***

Heatwaves affect human health via heat stress, heatstroke, and death, as well as exacerbations of underlying conditions that can lead to an increase in mortality from all causes of death (not just heatstroke). Older adults, children, city-dwellers, the poor, and people taking certain medications are at the highest risk during a heatwave. The number of heat-related deaths are projected to increase with climate change (Confalonieri et al. 2007).

Recent projections of the impacts of climate change on heatwaves in the Midwest, using two definitions of a heatwave (the warmest average minimum temperatures over three consecutive nights in a given year, and exceedance of particular thresholds, suggested an increase in the average heatwave frequency of about 24% for Chicago (from 1.7 to 2.1 heatwaves per year); 50% for Cincinnati (from 1.4 to 2.1 heatwaves per year); and 36% for St. Louis (from 1.4 to 1.9 heatwaves per year) (Ebi and Meehl 2007). The average duration of heatwaves was projected to increase by 21% for Chicago (from 7.3 to 8.8 days); by 22% for Cincinnati (from 8.8 to 10.7 days); and by 38% for St. Louis (from 10.3 to 14.2 days). Combining changes in duration and intensity of heatwaves implies an overall increase of about 70% in the annual number of heatwave days for the Midwest by the late 21st century. Moreover, these extreme days will be hotter on average than at present. The projections also suggested that areas such as the Northwest, where heatwaves are not severe at present and where use of air conditioning is less common, future increases in heatwave intensity could result in more heat-related illnesses and deaths.

Hayhoe et al. (2004), the most recent study focused on the U.S., projected the impacts of extreme heat on heat-related mortality in California. Taking some acclimatization into account (but no change in the prevalence of air conditioning), assuming a linear increase in heat-related mortality with increasing temperature, and assuming no change in the population, expected heat-related deaths in Los Angles were projected to increase (from a baseline of about 165 excess deaths annually) two- to three-fold under a low emission scenario and five- to sevenfold under a high emission scenario by 2070–2099.

Applying the magnitude of the 2003 European heatwave to five major U.S. cities (Detroit; New York; Philadelphia; St. Louis; and Washington, D.C.), Kalkstein et al. (2008) concluded that a heatwave of the same magnitude would increase excess heat-related deaths by more than five times the average. New York City's total projected excess deaths exceeded the national summer average for heat-related mortality, with the death rate approaching annual mortality rates for common causes of death, such as accidents.

Climate change is projected to increase the intensity and frequency of floods, droughts, and windstorms in many regions (IPCC 2007). The impacts of an extreme event,

including loss of life and livelihood, are determined by the physical characteristics of the event, attributes of the location affected, and interactions of these with human actions and social, economic, institutional, and other systems. The adverse health consequences of flooding and windstorms often are complex and far-reaching, and include the physical health effects experienced during the event or clean-up process, or from effects brought about by damage to infrastructure, including population displacement. The physical effects largely manifest themselves within weeks or months following the event, and may be direct (such as injuries) and indirect (such as water and food shortages and increased rates of vectorborne and other diseases). Extreme weather events are also associated with mental health effects, such as post-traumatic stress disorder, resulting from the experience of the event or from the recovery process. These psychological effects tend to be much longer lasting and may be worse than the direct physical effects.

***Air Pollutants***

Climate change may increase concentrations of selected air pollutants, particularly ozone in some regions, and decrease concentration of other pollutants, such as particulate matter. Air pollution concentrations are the result of interactions among local weather patterns, atmospheric circulation features, wind, topography, and other factors. Climate change might affect local to regional air quality directly through changes in chemical reaction rates, boundary layer heights that affect vertical mixing of pollutants, and changes in synoptic airflow patterns that govern pollutant transport. Indirect effects may result from increasing or decreasing anthropogenic emissions via changes in human behavior, or from altering the levels of biogenic emissions because of higher temperatures and land cover change. Establishing the scale (local, regional, global) and direction of change (improvements or deterioration) of air quality is challenging.

There is extensive literature documenting the adverse health impacts of exposure to elevated concentrations of air pollution, especially particulates with aerodynamic diameters under 10 and 2.5 micrometers, ozone[1], sulphur dioxide, nitrogen dioxide, carbon monoxide, and lead. More is known about the potential impact of climate change on ground-level ozone than on other air pollutants.

Acute exposure to elevated concentrations of ozone is associated with increased hospital admissions for pneumonia, chronic obstructive pulmonary disease, asthma, allergic rhinitis and other respiratory diseases, and with premature mortality (e.g. NRC 2008). Outdoor ozone concentrations and activity patterns are the primary determinants of ozone exposure. The risk of mortality is not limited to those who are at very high risk of death within a few days of exposure (NRC 2008). A NRC committee concluded that "*the association between short-term changes in ozone concentrations and mortality is generally linear throughout most of the concentration range, … . If there is a threshold, it is probably at a concentration below the current ambient air standard.*" (NRC 2008). In addition, there is limited evidence that chronic exposure to ozone increases mortality; if confirmed, then the total health burden of exposure to ozone would be much higher than current estimates (NRC 2008).

[1] The aerodynamic diameter of a particle determines the depth to which it will be inhaled into the lungs, and, therefore, the degree of damage that may be caused to various parts of the lung.

Changes in concentrations of ground-level ozone driven by scenarios of future emissions and /or weather patterns have been projected for Europe and North America (Confalonieri et al. 2007; Ebi and McGregor 2008). Increases in ozone concentrations will likely increase respiratory problems in susceptible individuals. Based on projections of county-level pollutant concentrations, summer ozone-related mortality was projected to increase by 4% in the New York area by the 2050s based on climatic changes alone (Knowlton et al. 2004).

***Infectious Diseases***

Climate change will likely have mixed effects on the health burdens of infectious diseases. Climate is a primary determinant of whether a particular location has environmental conditions suitable for the transmission of several vector-, rodent-, and tick-borne diseases, including West Nile virus, St. Louis encephalitis, Lyme disease, and dengue. A change in temperature may hinder or enhance vector and parasite development and survival, thus lengthening or shortening the season during which vectors and parasites survive. Small changes in temperature or precipitation may cause previously inhospitable altitudes or ecosystems to become conducive to disease transmission (or cause currently hospitable conditions to become inhospitable). The many determinants of infectious diseases often form an interconnected web with positive feedbacks between transmission dynamics and other factors, making modeling of the impacts of climate change challenging.

Several food- and waterborne diseases are climate sensitive, suggesting that climate change may affect their incidence and distribution. For example, studies report an approximately linear association between temperature and common forms of foodborne diseases such as salmonellosis (Confalonieri et al. 2007).

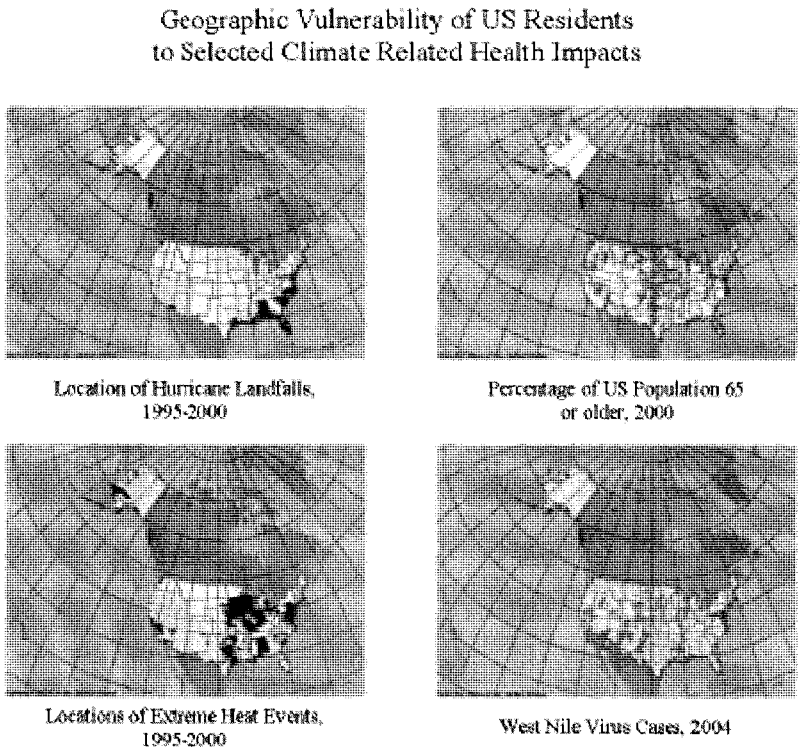
Recent studies report the occurrence of diseases in regions that have been considered too cold to support the pathogen (McLaughlin et al. 2005; Stephen et al. 2002). *Vibrio parahaemolyticus,* the leading cause of seafood-associated gastroenteritis in the U.S., is typically associated with the consumption of raw oysters gathered from warm-water estuaries (McLaughlin et al. 2005). One of the largest known outbreaks of *V. parahaemolyticus* in the U.S. occurred in Alaska, extending by 1000 km the northernmost documented source of oysters that cause this illness. Rising temperatures of ocean water seem to have contributed to the outbreak. An outbreak of *Cryptococcus gattii*, previously considered a tropical organism, occurred in southern Vancouver Island (Stephen et al. 2002). The incidence of medical visits for adverse reactions to insect stings and bites in three independent patient databases has increased during the past decade in Alaska, which has been associated with temperature changes in the same region (Demain et al in press).

***Particularly Vulnerable Populations and Regions***

Vulnerability to climate change will vary between and within populations. Sub-populations that are most vulnerable to the health impacts of climate change depend on the region of interest, the health outcome, and population characteristics, including human, institutional, social, and economic capacity, distribution of income, provision of medical care, and access to adequate nutrition. In general, children, older adults, those

with chronic disease, and the poor and disadvantaged are most at risk. Figure 1 shows counties with existing vulnerabilities to climate-sensitive health outcomes.

**Figure 1: Counties with Existing Vulnerabilities to Climate-Sensitive Health Outcomes**




## 2.0 Public Health Capacity to Address the Risks of Climate Change

Realistically assessing the potential health effects of climate change must include consideration of the capacity to manage the impacts of new and changing climatic conditions. Individuals, communities, governments, and other organizations currently engage in a wide range of actions to identify and prevent adverse health outcomes associated with weather and climate, such as heatwaves, wildfires, hurricanes, etc. Although these actions are generally viewed as having been largely successful historically, two recent surveys suggest that climate change will challenge the ability of current programs and activities to control climate-sensitive health determinants and outcomes (Balbus et al. 2008; Maibach et al. 2008; Wells Bedsworth 2008). Although some level of preparedness exists, there is a long way to go before the country's adaptive capacity is at a sufficient level. The preparedness gap includes not just infrastructure and

capacity, but also fundamental knowledge and the availability of reliable decision support tools. Preventing additional morbidity and mortality will require modification of current and implementation of new programs and activities to increase resilience to climate change, taking into consideration the local context, including socio-economic, geographic, and other factors. Research is needed to identify effective and efficient programs and activities, as well as how to successfully transfer lessons learned to other communities to assure protection of public health (Ebi et al. 2008).

The risks of climate change are likely to place extraordinary demands on public health programs and activities designed to protect the health and safety of U.S. residents and visitors. Increases in illnesses, injuries, and deaths would be expected unless policies and measures are developed to ensure effective functioning of these programs and activities. National, state, and local plans are needed to ensure sufficient public health capacity during and following extreme events such as flooding, storms and storm surges, and to address outbreaks of climate-related outbreaks of vector-, food-, and waterborne diseases. This capacity must be present, consistent, and effective in analyzing the safety of drinking water, monitoring for the appearance of vectorborne diseases, and providing acute and chronic care for persons suffering from the effects of climate-related events. Constraints include the financial, human, and institutional capacity at all levels of government and institutional service providers.

### 3.0 Managing the Projected Health Risks of Climate Change

Adaptation and mitigation are the primary approaches for addressing the risks of climate change; they are not mutually exclusive; co-benefits to human health can result concurrently with implementation of mitigation actions. Neither is sufficient in itself; focusing only on mitigation would leave communities ill-prepared for changes expected in the short term; and focusing only on adaptation would increase the amount of climate change to which future societies would need to cope.

Viewing adaptation within a risk management framework highlights some of the key differences between climate change and other environmental risk factors, including that the exposure cannot be prevented (i.e. increases in the frequency, intensity, and length of many extreme weather events); the rate of change is likely to increase over the next several decades; and the risks will vary over temporal and spatial scales, with the extent of impacts dependent on local and national factors. Therefore, adaptation will be a continual process of attempting to prevent adverse impacts from changing exposures and vulnerabilities.

Climate change will make it more difficult to control climate-sensitive health determinants and outcomes. Therefore, health policies need to explicitly incorporate climate-related risks in order to maintain current levels of control. In most cases, the primary response will be to enhance current health risk management activities. The health determinants and outcomes that are projected to increase with climate change are problems today. In some cases, programs will need to be implemented in new regions; in others, climate change may reduce current infectious disease burdens. The degree to which programs and measures will need to be augmented to address the additional pressures due to climate change will depend on factors such as the current burden of

climate-sensitive health outcomes, the effectiveness of current interventions, projections of where, when, and how the health burden may change with changes in climate and climate variability, the feasibility of implementing additional cost-effective interventions, other stressors that might increase or decrease resilience to impacts, and the social, economic, and political context within which interventions are implemented (Ebi et al. 2006). Examples of adaptation measures range from developing and deploying early warning systems and emergency response plans that specifically incorporate projections of climate change-related health risks to establishing surveillance programs in regions where projections suggest disease vectors may change their geographic range. Adaptation policies and measures need to consider how to effectively and efficiently reduce climate-related health risks in the context of sustainable development, considering projected demographic, economic, institutional, technologic, and other changes.

Because fossil fuel combustion is a source of urban air pollutants and greenhouse gases, policies to reduce greenhouse gas emissions may have health benefits in the near- and long-term. There are potential synergies in reducing greenhouse gas emissions and improving population health via sustainable transport systems that make more use of public transport, walking, and cycling.

**4.0 The Human Impacts of Climate Change Outside the U.S. Can Affect the Population Health in the U.S.**

Health security in the U.S. is influenced by risks outside her borders, as illustrated by the introduction and spread of West Nile virus and the concerns over the possible spread of SARS in the U.S. Globalization, increased travel and trade, immigration, and other factors can introduce new health risks, and disasters can increase the flow of refugees. *Plasmodium vivax* malaria, dengue fever, and other vectorborne diseases were once prevalent in the U.S., and the mosquitoes that can carry these diseases remain common in the U.S. Climate change is providing an opportunity for these mosquitoes to increase their geographic range; this could put more people at risk for introduced diseases if vector control programs are insufficient or not prepared. Better understanding of how climate change could alter the current distribution and incidence of climate-sensitive health outcomes throughout the world is needed to ensure U.S.-based programs and activities have adequate knowledge and resources to protect the health of our citizens.

**5.0 Health Impact Assessments Are Needed of Policies and Technologies Being Developed to Reduce Climate Change Risks**

The policies and technologies being developed to reduce the risks of climate change, from energy efficiency policies to carbon capture and storage, may have considerable health consequences. Therefore, a mechanism is required to assess the consequences of proposed mitigation and adaptation policies and measures prior to their adoption. Health Impact Assessments (HIAs) are a proven approach to ensuring that potential public health concerns are identified and addressed before they become a problem. According to the World Health Organization, "HIA provides decision makers with information about how any policy, programme or project may affect the health of people. HIA seeks to influence decision makers to improve the proposal." (http://www.who.int/hia/en) HIAs

includes consideration of potential alternatives to reduce or mitigate potential health consequences of a proposed policy, as well as monitoring and evaluation of the adopted policy's implementation, to make corrections as needed to ensure the policy's effectiveness and its protection of human health. HIAs also can be used to identify the co-benefits of smart growth and development policies.

**6.0 Federal Coordination is Needed of Research on the Health Impacts of Climate Change in the U.S.**

Effectively addressing the health risks of climate variability and change will require wide-ranging responses from Federal and State agencies and departments. Because the health risks of and public health responses to climate change cover a broad range of issues, and because the risk and responses will change over temporal and spatial scales, there should be Federal coordination of programs and activities, within the CCSP or a similar organization, to ensure that funding focuses on critical research needs to address current gaps and those likely to arise within the next few decades. Programs and activities designed to address climate change and health issues should be established within all Federal agencies whose mandates include human health, including Departments of Commerce (specifically the National Oceanographic and Atmospheric Administration), Health and Human Services (particularly the Centers for Disease Control and Prevention), Homeland Security, Environmental Protection Agency, the National Institutes of Health, National Science Foundation, and the U.S. Geological Survey.

A robust research strategy to address the health risks of climate change, including the health aspects of climate mitigation and adaptation policies, should integrate four broad research activities: characterizing associations between weather/climate and health based on observed data; identifying observed effects of climate change on health; projecting health impacts using models; and identifying, prioritizing, evaluating, implementing, and monitoring effective and timely response options (including adaptation and mitigation). Key public health research categories that address these essential services include surveillance and monitoring; field, laboratory, and epidemiologic research; model development; development of decision support tools; and education and capacity building of the public and public health and health care professionals (Frumkin et al. 2008).

**7.0 Research Funding to Understand the Health Impacts of Climate Change in the United States is Inadequate**

Based on data available from agency websites, it appears that current Federal funding directed at understanding and addressing the health risks of climate change is approximately $3 million annually; this number would be approximately $1 million without new solicitations from U.S. EPA. These estimates are significantly less than funding figures provided to CCSP, and are inadequate to address the real risks that climate change poses for U.S. populations.

The inadequate level of U.S. funding appears to be due to the low priority placed on identifying and managing the health risks of climate change by Congress and the Federal

government. There are five over-arching goals for CCSP for fiscal year 2009 (U.S. CCSP 2008). Two are relevant to human health. Theme 4 is to understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes. However, the three identified focus areas do not explicitly mention human health as a priority (focus areas are to: improve knowledge of the sensitivity of ecosystems and economic sectors to global climate variability and change; identify and provide scientific inputs for evaluating adaptation options, in cooperation with mission-oriented agencies and other resource managers; and improve understanding of how changes in ecosystems (including managed ecosystems such as croplands) and human infrastructure interact over long time periods). Theme 5 is to explore the uses and identify the limits of evolving knowledge to manage the risks and opportunities related to climate variability and change; again, the three identified focus areas do not focus on human health (support informed public discussion of issues of particular importance to U.S. decisions by conducting research and providing scientific synthesis and assessment reports; support adaptive management and planning for resources and physical infrastructure sensitive to climate variability and change; build new partnerships with public and private sector entities that can benefit both research and decision-making; and support policymaking by conducting comparative analyses and evaluations of the socioeconomic and environmental consequences of response options). Understanding, avoiding, preparing for, and managing the health risks of climate change should be explicitly mentioned in CCSP goals.

More importantly, given the current and projected health risks of climate change in the U.S., Congress needs to allocate funds to Federal agencies whose mission mandates include human health; these agencies should maintain and enhance programs (and appropriate funding) to specifically address climate change risks in a timely and efficient manner. Based on the approach used for the Federal program in airborne particulate matter, and acknowledging the additional complexity of addressing the health risks of climate change, the level of Federal funding directed at climate change and health research should be more than $200 million annually (Ebi et al. submitted).

This suggested level of effort must rely on continued robust programs on research relevant to climate change and health. For example, U.S. EPA's Global Change Research Program recently completed a nine-year-long assessment of the implications of climate change for regional air quality that provides a basis for significant advances in understanding how projected changes in air quality could affect human health. NIEHS and CDC have conducted extensive research on asthma, vectorborne diseases, and other climate-sensitive health outcome that is required for understanding and predicting weather/climate exposure-response relationships, seeking evidence of whether climate change has affected human health, projecting the future geographic range and incidence of climate-sensitive health outcomes under a range of possible development pathways, and developing effective and timely adaptation and mitigation options.

Climate change is not a pollutant in the classical sense used in public health; it is a projected to fundamentally alter the systems on which our society relies, including air, water, agriculture, and ecosystems. Responses to climate change may alter energy, transportation, and other systems required for our societies to function. The health risks of climate change may arise from changes in any of these systems. Better understanding

is needed of these systems interactions with health, including risks and opportunities for interventions to improve population health. Ensuring that a Federal research program prepares the U.S. for the current and projected health impacts of climate change would be facilitated by establishing a standing committee within the National Academy of Sciences to advise on the size, priorities, and balance of such a program, through independent and regular evaluations of the state of knowledge and critical research gaps to address current and projected health risks.

Evidence is accumulating that climate change is adversely affecting human health in other parts of the world (i.e. Confalonieri et al. 2007). The lack of attention from the Federal government on the health risks of climate change to U.S. populations is needlessly putting people at risk.

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Mr. MARKEY. Thank you, Dr. Ebi. Just for the members' information, the House is in recess subject to the call of the chair, so we are going to have a good stretch here in order to the listen to the witnesses and to cross-examine them.

Our next witness is Dr. Frank Ackerman, an economist who has written extensively on environmental economics and climate change. He is the senior economist at the Stockholm Environmental Institute, the U.S. Center as well as a senior research fellow at the Global Development and Environmental Institute at Tufts University. We welcome you, Dr. Ackerman. Whenever you are ready, please begin.

**STATEMENT OF FRANK ACKERMAN, SENIOR ECONOMIST, STOCKHOLM ENVIRONMENT INSTITUTE U.S. CENTER, TUFTS UNIVERSITY**

Mr. ACKERMAN. Thank you for inviting my testimony.

As several people have said already today, the debate has largely shifted from science to economics. Climate change is real. It is caused by human activity. It is going to be increasingly bad for us. The question now before us is, can we afford to do anything about it. As a group of prominent economists including several Nobel laureates said, the most expensive thing we can do is nothing. There is a growing recognition in the economics profession of the costs of doing nothing. The Stern Review sponsored by the British government was a major step forward in understanding that. As has been mentioned, the Stern estimate of the cost of doing nothing ranged depending on how you understand the damages from 5 percent to 20 percent of world output compared to the cost of solving the problem, eliminating most of those impacts which Stern estimated at 1 percent of world output for some decades. There are many studies of local and regional impacts of climate change, varied impacts on different ecosystems, different climate regions within the United States. There is an excellent study by Matias Ruth of the University of Maryland reviewing a lot of these.

My research, which is described in my written testimony, was in response to requests for a total dollar estimate for the costs of inaction for the United States. We did one study of the United States and a study looking more in depth at Florida. We found that just a few categories of damages would amount to 1.5 percent of U.S. income by the end of this century. For Florida, which is much more in harm's way, four categories of damages could amount to as much as 5 percent of the State income by the end of the century. The categories that we looked are hurricane damages, the effects of sea level rise solely on residential real estate, not on all the properties in the State, cost to the electrical system of the changes in demand, costs of more expensive and difficult water supply for the United States. For Florida, we were not able to produce a similar water estimate but we estimated the costs of losses to the State's very important tourism industry.

Now, I would emphasize that these numbers, while they are larger than the 1 percent estimate of the costs of action, they are partial estimates of the costs of inaction. There is no such thing as a total dollar estimate for the costs of inaction. Lives will be lost to climate change if we do nothing about it. There is no meaningful

way to put a dollar cost on those but you can't forget it. The costs of Hurricane Katrina were not just property losses, there were also more than 1,000 people who died there. Damages to nature and extinction of species, likewise, have no meaningful price. Turning to economic categories, we did not estimate agricultural losses except to the extent they were included in water losses. We didn't estimate wildfires and forest die-off costs or the costs of floods in the Midwest and California and elsewhere. We didn't look at the cost of infrastructure along the coasts other than the cost to residential real estate, and a very important point, which has come out in the economics literature lately, is the importance of looking at worst-case risks rather than averages. Climate change will get worse on average, and the worst-case risks are indeed ominous. The risks of an abrupt discontinuity climate catastrophe has to be taken seriously. When people buy insurance, they buy insurance against worst cases, not average. On average you don't need fire insurance. On average you have 99 percent confidence that you don't need fire insurance. You can live a richer life if you cancel the fire insurance. Not taking seriously the worst-case risks the same way that we do when we buy fire insurance is taking a huge gamble. The future is only going to happen once. If we were lucky, we wouldn't need insurance but that is not the way anybody thinks about these risks in their ordinary life.

So we concluded that climate change will be bad for the economy. Just a few categories of economic damages for the United States as a whole exceed the cost of action. For Florida, it is much worse. We did a similar short study of the Caribbean, where we found devastating costs to the island economies that are completely at risk from climate change. Those are likely to cause a flood of refugees, as the speakers discussing security have mentioned. There are real issues about refugees caused by climate change. Where are people leaving the Caribbean because of climate change going to go? Probably not to Venezuela.

And finally, there is an international dimension to this. I have been to a lot of climate change conferences in the last 8 years. It has been embarrassing to go to them as an American. People tend to come at you again and again about what are you thinking of, doing nothing about it, and why we should do anything about it when the world's largest economy is doing nothing. So I am very happy to see that we have a chance to change that and to go back and challenge the rest of the world to keep up with us.

Thank you.

[The prepared statement of Mr. Ackerman follows:]


*SEI-US is an independent research affiliate of Tufts University*

# Climate Change: The Costs of Inaction

Testimony presented to:

United States Congress
House Committee on Energy and Commerce
Subcommittee on Energy and Environment

Hearing on

"The Climate Crisis:
National Security, Public Health, and Economic Threats"

February 12, 2009

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Mr. Chairman and members of the committee,

Thank you for the invitation to testify on my research on the costs of climate change. This hearing comes at a crucial juncture – and not only because the new administration is beginning to make changes in US climate policies. New initiatives are on the table, in part, because there has been a fundamental shift in the terms of the debate, with the focus of controversy moving from science to economics. In the realm of science, the influence of the isolated handful of climate skeptics is rapidly waning; the world's scientists have never been so unanimous, and so ominous, in their warnings of future hazards.

While the climate *science* debate is approaching closure, the climate *economics* debate is still wide open. Climate change is happening, it is threatening our future well-being – but how much can we afford to do about it? The most powerful argument for inaction today is no longer skepticism about the science, but rather the claim that the costs of reducing emissions would be intolerable. The damage to the economy, it is alleged, would be worse than the climate problem we are attempting to solve.

The economic argument for inaction is wrong on two counts: it exaggerates the costs of reducing emissions, and it understates the harm that will occur if we continue to do little or nothing about climate change. My testimony primarily addresses the second point, on the costs of inaction.

On the first point, the costs of reducing emissions, Nicholas Stern's detailed review of the economics of climate change, for the British government, estimated that we need to spend one percent of global income for several decades to bring carbon dioxide emissions down to a relatively safe level. More recent studies of the costs of carbon reduction technologies by McKinsey & Company, an international consulting firm, have led to very similar estimates. The occasional claims of much higher costs are not nearly as well researched and documented as the Stern and McKinsey estimates. Thus one percent of global income is the best available estimate of the cost of solving the climate problem.

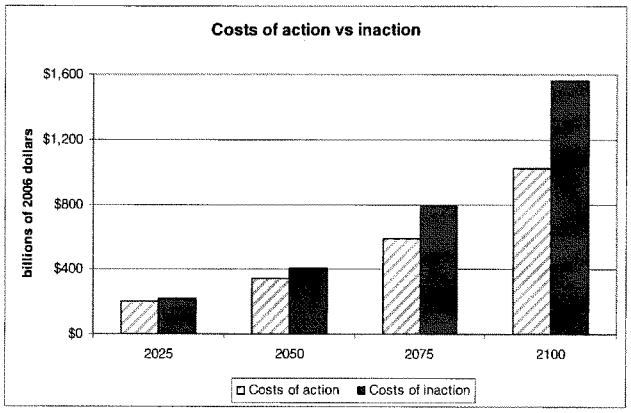
In contrast, my research shows that for the United States as a whole, even a partial accounting of the costs of *inaction* exceeds one percent of GDP, and rises steadily over time. For some parts of the country, such as Florida, a similar, partial accounting of the costs of inaction reaches 5 percent of state income within this century. For particularly vulnerable parts of the world, such as the islands of the Caribbean, the costs will be disastrously greater – with one likely consequence being a much-increased flow of refugees out of that region.

Damages that will result from inaction include (but are not limited to):

- the impacts of increasingly severe hurricanes
- more coastal property at risk from rising sea levels and storm surges
- increased energy costs for air conditioning as temperatures rise
- growing scarcity and rising costs for water
- losses in agriculture due to hotter and drier conditions
- losses of tourism revenue as weather conditions worsen

A graphic comparison of the annual costs of action (one percent of GDP) versus my partial accounting of the annual costs of inaction is shown in Figure 1. There are real costs to reducing emissions; there are much worse, bigger costs to doing nothing. And my analysis includes only a part of the benefits of taking action to reduce emissions.

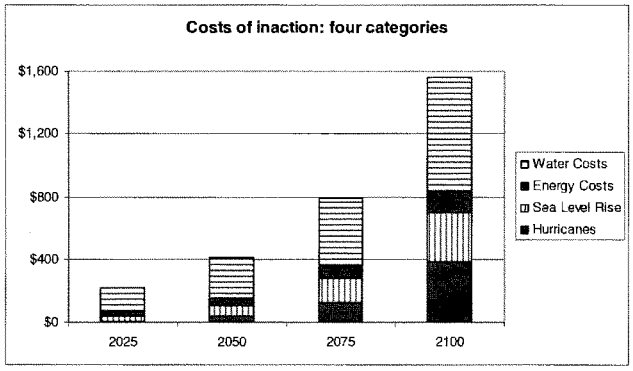
**Figure 1**




The principal categories of costs of inaction that are estimated in my research are shown in Figure 2 below, and described in my detailed testimony.

The farther we look into the future, the worse that the costs of inaction will become. The longer we do nothing, the greater the risks of an irreversible climate catastrophe, such as a massive rise in sea levels, that could make the world unable to support anything like the current levels of population and economic activity. The costs and risks of inaction are overwhelmingly worse than the moderate and manageable costs of an immediate effort to reduce carbon emissions.

**Figure 2**




My detailed testimony draws on studies done at the Stockholm Environment Institute-US Center, a research center at Tufts University, in which I have collaborated with another economist, Dr. Elizabeth A. Stanton, as well as Ramón Bueno and Cornelia Herzfeld. For more information on our research on climate economics, please see http://www.sei-us.org/climate-and-energy/climate-economics.html . This website includes links to the studies of the costs of inaction for the US as a whole[1], for Florida[2], and for the Caribbean region[3], which together form the basis for my testimony today. My overall perspective on the economics of climate change is described in my recent book, *Can We Afford the Future? Economics for a Warming World* (London and New York: Zed Books, 2009).

I will be happy to provide any additional information related to this testimony, and to answer any questions that you may have about it.

Sincerely,

Dr. Frank Ackerman

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[1] Frank Ackerman and Elizabeth A. Stanton, *The Cost of Climate Change: What We'll Pay if Global Warming Continues Unchecked*, May 2008, http://www.nrdc.org/globalwarming/cost/contents.asp. See also the more technical supporting document, Ackerman and Stanton, *Climate Change and the U.S. Economy: The Costs of Inaction*, May 2008, http://www.sei-us.org/climate-and-energy/US_Costs_of_Inaction.doc.

[2] Elizabeth A. Stanton and Frank Ackerman, *Florida and Climate Change: The Costs of Inaction*, November 2007, http://www.sei-us.org/climate-and-energy/Florida_Inaction_Cost.html.

[3] Ramón Bueno, Cornelia Herzfeld, Elizabeth A. Stanton, and Frank Ackerman, *The Caribbean and Climate Change: The Costs of Inaction*, May 2008, http://www.sei-us.org/climate-and-energy/Caribbean_Inaction_Cost.htm.

**Introduction: The Costs of Inaction**

A scientific consensus has been reached: The earth's climate is changing for the worse, as a result of anthropogenic (human-caused) changes to the composition of the atmosphere. If everyone works together, all around the world, to reduce the concentration of greenhouse gases in our atmosphere, we can slow and even stop climate change. If we fail to do so, the consequences will be increasingly painful – and expensive.

My research group's analyses compare the economic consequences of two possible climate futures: The *business-as-usual* case, the worst likely result of emissions that continue to increase over time, unchecked by public policy, and the *rapid stabilization* case, the best likely result of a program of rapid, ambitious worldwide abatement initiatives.[4] It is too late to avoid all climate damages; even the rapid stabilization case involves significant losses due to climate change. However, the difference between the two scenarios – between the comparatively small losses under rapid stabilization and the huge losses under business-as-usual – is avoidable if we act soon.[5] Failure to act means that we will incur a much bigger and more painful climate loss rather than a smaller and more bearable one. The difference between the two is the cost of inaction.

My testimony begins with our analysis of the costs of inaction for the U.S., and then turns to our findings for Florida and for the Caribbean. A brief conclusion summarizes the message and the meaning of this testimony for climate policy decisions.

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[4] On many climate projections, the IPCC issues a range of possible forecasts, with estimates of probabilities attached. Here we differ from the simple approach of reporting the median of the IPCC range. Since the future will only happen once, and we want to know how bad the risks of future damages could be, the median is misleading: there is a 50-50 chance that the future will be worse than that, perhaps much worse. Instead, we use the upper (worst) limit of what IPCC calls the "likely" range of outcomes – which they define to mean the 17$^{th}$ to the 83$^{rd}$ percentiles. That is, we report the 83$^{rd}$ percentile of IPCC forecasts, generally using their rapidly growing A2 scenario to represent business as usual. Using similar logic, our best case or rapid stabilization scenario represents the 17$^{th}$ percentile outcome of the more slowly growing B1 scenario – or as good as it is likely to get, according to IPCC projections. Note that IPCC projects a one-in-six chance that the worst case is worse, and the same odds that the best case is better, than our estimates.

[5] Throughout our analyses we assume that the size of the economy and population will be the same in both scenarios. This (perhaps unrealistic) assumption is useful in clarifying the meaning of our two cases, and the contrast between them: all the economic differences between the business-as-usual and rapid stabilization cases reflect different climate impacts applied to the same economy, not changes in the underlying projections of output or population.

*U.S. Costs of Inaction: Business-As-Usual Scenario*

In the business-as-usual case, the average annual temperature in most of the mainland 48 states will increase 12 to 13°F by 2100 – a little more in the nation's interior, a little less on the coasts. For a few areas of the country, the average annual temperature increase will be near or below the global mean: for the Gulf Coast and Florida, 10°F; and for Hawaii and U.S. territories in the Pacific and the Caribbean, 7°F by 2100. Alaska, like all of the Arctic, will experience an even greater increase in average temperature than the U.S. mainland. On average, Alaska's annual temperature will increase by a remarkable 18°F by 2100, but temperature increases may be even higher in the northernmost reaches of Alaska. Table 1 shows the progression of these temperature changes over time.

**Table 1: Business-As-Usual Case: U.S. Annual Average Temperatures by Region**

| *in degrees Fahrenheit above year 2000 temperature* | 2025 | 2050 | 2075 | 2100 |
|---|---|---|---|---|
| **Alaska** | 4.4 | 8.8 | 13.2 | 17.6 |
| **U.S. Central** | 3.3 | 6.6 | 9.9 | 13.1 |
| **U.S. East** | 3.1 | 6.1 | 9.2 | 12.2 |
| **U.S. West** | 3.1 | 6.1 | 9.2 | 12.2 |
| **U.S. Gulf Coast and Florida** | 2.4 | 4.9 | 7.3 | 9.7 |
| Global Mean | 2.2 | 4.3 | 6.5 | 8.6 |
| **Hawaii and the Pacific** | 1.8 | 3.6 | 5.4 | 7.2 |
| **Puerto Rico and the Caribbean** | 1.8 | 3.6 | 5.4 | 7.2 |

These temperature increases represent a fundamental change to the climate of the United States. In the business-as-usual case, the predicted annual average temperature for Anchorage, Alaska in 2100 – 53°F – is the historical annual average temperature for New York City. Under this scenario, the northern tier of mainland states from Washington to Maine will come to have the current climate of the mid-latitude states, those stretching from Northern California to New Jersey. Those middle tier states will take on the climate of the southern states, while the southern states will become more like Mexico and Central America. Annual average temperatures in Honolulu and Phoenix will match some of the hottest cities in the world today – Acapulco, Mexico and Bangkok, Thailand. The United States' hottest big cities, Miami and San Juan, Puerto Rico, will reach annual averages of 85 and 87°F, respectively – hotter than any major city in the world today.

Changes in precipitation patterns are likely to differ for each region of the United States. Alaska's precipitation will increase by 10 to 20 percent, mostly from increased snowfall. The Great Lakes and Northeast states will receive 5 percent more precipitation each year,

mostly in winter. The U.S. Southwest, including California and Texas, will experience a decrease in precipitation, down 5 to 15 percent, mostly from less winter rain. The U.S. Gulf Coast and Florida will also receive 5 to 10 percent less rain each year. There will also be a higher risk of winter flooding, earlier peak river flows for snow and glacier-fed streams; lower summer soil moisture and river flows; and a shrinkage of sea ice, glaciers and permafrost. Climate change also affects storm intensity; specifically, Atlantic hurricanes and Pacific typhoons will become more destructive.

Our estimates for sea-level rise under the business-as-usual case diverge somewhat from the scenarios presented in the latest IPCC report. This area of climate science has been developing rapidly, but the most recent advances were released too late for inclusion in the IPCC process. Based on our reading of this recent work, we use an estimate of 45 inches by 2100.[6]

We consider four case studies of the economic consequences of climate change under the business-as-usual climate scenario for the United States:

1) increasing intensity of Atlantic and Gulf Coast hurricanes
2) inundation of coastal residential real estate with sea-level rise
3) changing patterns of energy supply and consumption
4) changing patterns of water supply and use, including effects on agriculture

These are far from the only consequences of climate change; the costs in these four areas are only a partial accounting of the economic damage that will result from business as usual. Nonetheless, costs in these four areas will, if present trends continue, amount to $1.8 trillion (in today's dollars), or 1.8 percent of U.S. output per year by 2100 in the business-as-usual case. Once the much smaller, unavoidable costs under the rapid stabilization case (discussed below) are subtracted, the "cost of inaction" or the difference between the business-as-usual and rapid stabilization cases could be more than $1.5 trillion or 1.5 percent of U.S. output *per year* by 2100.

*Hurricane damages.* In the business-as-usual scenario, hurricane intensity will increase, with more of the most intense types of hurricanes occurring as sea-surface temperatures rise. Greater damages from more intense storms would come on top of the more severe storm surges that will result from higher sea levels. We consider three factors that are expected to increase damages and deaths resulting from future hurricanes; each of these three factors is independent of the other two. The first is coastal development and population growth – the more property and people that are in the path of a hurricane, the higher the damages and deaths. Second, as sea levels rise, even with the intensity of storms remaining stable, the same hurricane results in greater damages and deaths from

[6] For details, see Frank Ackerman and Elizabeth A. Stanton, *Climate Change and the U.S. Economy: The Costs of Inaction*, pp.7-8, http://www.sei-us.org/climate-and-energy/US_Costs_of_Inaction.doc.

storm surges, flooding, and erosion. Third, hurricane intensity may increase as sea-surface temperatures rise. Combining these effects together, the predicted increase to U.S. hurricane damages for the year 2100 is $397 billion, or 0.39 percent of U.S. output in the business-as-usual case.[7]

*Rising sea levels.* The effects of climate change will have severe consequences for low-lying U.S. coastal real estate. If nothing were done to hold back rising waters, sea-level rise would simply inundate many properties in low-lying, coastal areas. Even those properties that remained above water would be more likely to sustain storm damage, as encroachment of the sea allows storm surges to reach inland areas that were not previously affected. In the business-as-usual case, the annual residential real estate losses in the 48 mainland states rise to $360 billion or 0.35 percent of U.S. output by 2100. No one expects coastal property owners to wait passively for these damages to occur; those who can afford to do so will undoubtedly seek to protect their properties. But all the available methods for protection against sea-level rise are problematical and expensive. It is difficult to imagine any of them being used on a large enough scale to shelter all low-lying U.S. coastal lands from the rising seas of the 21st century.

*Energy demand.* Climate change will affect both the demand for and the supply of energy: hotter temperatures will mean more air conditioning and less heating for consumers – and more difficult and expensive operating conditions for electric power plants. In the business-as-usual case, increasing average temperatures drive up the costs of electricity above population and per-capita increases. Not surprisingly, electricity demand rises most rapidly in the Southeast and Southwest, as those regions experience more uncomfortably hot days. By the same token, our model projects that while the Northeast and Midwest also have rising air conditioning costs, those costs are largely offset by reduced demand for natural gas and heating oil expenditures. That is, speaking very roughly, the colder half of the country nearly breaks even on energy costs, experiencing reduced heating and increased air conditioning costs of the same magnitude. The warmer half of the country, where heating costs are already small, suffers a substantial net increase in energy costs due to rising air conditioning use.

Overall costs in the energy sector in the business-as-usual case, combining increased costs for electricity and for new air conditioners, net of decreases in heating fuel costs, add up to $141 billion per year by 2100, or 0.14 percent of projected U.S. output.

*Water supply.* In the business-as-usual future, problems of water supply will become more serious, as much hotter and in many areas drier conditions will increase demand. The average temperature increase of 12-13°F across most of the country, and the decrease

[7] These numbers represent a 6 percent reduction from our previously reported hurricane damage estimates, to correct a technical error in the original numbers that led to a 6 percent overestimate, pointed out by Roger Pielke Jr. (personal correspondence).

in precipitation across the South and Southwest, as described above, will lead to water scarcity and increased costs in much of the country. Responses are likely to include intensified water conservation measures, improved treatment and recycling of wastewater, construction and upgrading of cooling towers to reduce power plant water needs, and a reduction in the extent of irrigated agriculture. Extrapolating from the best available past research, we find that the costs of business-as-usual for water supply could reach $950 billion per year by 2100, while the anticipated gains in crop yields may be small, and would in any case vanish by mid-century.

The annual costs of these four effects alone adds up to $1.8 trillion in 2100 or 1.8 percent of U.S. output in the business-as-usual scenario, as summarized in Table 3 below. The total cost of these four types of damages, however, only represents a lower limit on the total cost of the business-as-usual scenario; many other kinds of damages, while also likely to have important effects on the U.S. economy, are more difficult to estimate. Damage to commercial real estate from inundation, damage to or obsolesce of public and private infrastructure from rapidly changing temperatures, and losses to regional tourism industries as the best summer and winter vacation climates migrate north – just to name a few – are all likely effects of climate change that may be costly in the United States. Effects on human health, natural environments, and endangered species add other important climate damages, which are difficult or impossible to price.

***U.S. Costs of Inaction: Rapid Stabilization Scenario***

With immediate, large-scale reductions in greenhouse gas emissions, it is still possible for changes in the world's climate to remain relatively small. The rapid stabilization case is an optimistic estimate of the impacts of the most rigorous policy prescription under discussion today: "80 by 2050", or an 80 percent reduction in U.S. emissions by 2050, accompanied by a 50 percent reduction in total world emissions and continuing reductions thereafter. By 2100 in the rapid stabilization case, U.S. temperatures rise by 2 to 4°F (see Table 2) and sea levels rise 7 inches, but precipitation levels and other climatic trends remain at their historical levels.

**Table 2: Rapid Stabilization Case: U.S. Annual Average Temperatures by Region**

| *in degrees Fahrenheit above year 2000 temperature* | 2025 | 2050 | 2075 | 2100 |
|---|---|---|---|---|
| **Alaska** | 0.9 | 1.8 | 2.8 | 3.7 |
| **U.S. Central** | 0.8 | 1.5 | 2.3 | 3.0 |
| **U.S. East** | 0.7 | 1.4 | 2.2 | 2.9 |
| **U.S. West** | 0.7 | 1.4 | 2.2 | 2.9 |
| **U.S. Gulf Coast and Florida** | 0.6 | 1.1 | 1.7 | 2.2 |
| **Global Mean** | 0.4 | 0.9 | 1.3 | 1.8 |
| **Hawaii and the Pacific** | 0.4 | 0.8 | 1.2 | 1.6 |
| **Puerto Rico and the Caribbean** | 0.4 | 0.8 | 1.2 | 1.6 |

A small change in annual average temperatures can mean a big difference to a local climate. For example, the historical average annual temperature is 50°F in Boston, 53°F in New York City, and 56°F in Washington D.C. The rapid stabilization scenario still represents a significant change to local climates throughout the United States in the next century. Three degrees Fahrenheit is a big change, but if it happens at a slow enough pace, each locality should be able to adapt to its new climate. Of course, this adaptation will not be costless.

The area of the United States that will suffer the most extreme impacts, even in the rapid stabilization case, is Alaska, where glaciers, sea ice, and permafrost are already retreating today, and an even greater upheaval to ecosystems, infrastructure, and industry can be expected in the decades to come. U.S. Gulf States, Florida, Hawaii, and U.S. territories in the Pacific and the Caribbean, in contrast, will experience smaller temperature changes – much closer to the global mean – than the majority of U.S. states. On the other hand, island and coastal regions are more exposed than the interior of the country to other aspects of climate change, such as increased storm damages and sea-level rise.

*Hurricane damages.* In the rapid stabilization case, hurricane damages will be only slightly worse than current conditions. U.S. hurricane damages for the rapid stabilization case are projected to be $12 billion per year by 2100, over and above current average damages.

*Rising sea levels.* In the rapid stabilization case, we assume that the value of U.S. coastal real estate has grown in proportion to GDP, and that annual damages will be proportional to sea level and to GDP. Using the projected 7 inches of sea-level rise by 2100, residential real estate losses from inundation rise to $46 billion annually by 2100.

*Energy demand.* The milder changes in climate under the rapid stabilization scenario lead

to modest net increases in energy costs, amounting to $8 billion by 2100.

*Water use.* As temperatures rise, more water will be needed for irrigation, power plant cooling, household needs, and other uses. Moreover, a higher air temperature leads to faster evaporation; this could outweigh the gains from moderate increases in rainfall in some areas, leaving a smaller amount of water available in rivers and reservoirs. The water sector costs for the rapid stabilization case reach $220 billion in 2100; this is an important cost, but still far below the economic burden for water supply under business as usual.

In the rapid stabilization scenario the annual costs of these four effects alone adds up to $287 billion in 2100, or 0.28 percent of U.S. output, as summarized in Table 3 below.

***U.S. Costs of Inaction: Summary***

How much can we reduce these climate-induced losses by limiting our emissions of greenhouse gases? It is, unfortunately, no longer possible to avoid all adverse climate impacts. Some change from the pre-industrial climate has already taken place, and more is bound to occur as a result of greenhouse gases in the atmosphere, as well as the additional emissions that will be released in the very near future (too soon for policy changes to take effect).

The cost of inaction is the difference between the estimates for the business-as-usual and rapid stabilization cases, summarized in Table 3. The annual cost of inaction – the difference between the two cases – reaches $1.56 trillion, or 1.53 percent of U.S. output by 2100. And there are many other categories of costs that will be imposed by climate change, beyond the four areas we have examined; the total cost of inaction is inevitably much greater.

The costs we have estimated are not evenly distributed throughout the country. Hurricane damages are experienced almost entirely in the southeastern coastal states, on the Gulf Coast and the Atlantic (Pacific storms that affect Hawaii and the West Coast are not included in this calculation). Sea-level rise, of course, affects coastal areas. Energy costs are heavily concentrated in southern states; many northern states would enjoy reductions in winter heating costs that are roughly comparable to increased summer electricity expenses. Water supply costs are concentrated in areas that become drier than at present, particularly the Southeast and Southwest. Costs experienced in Alaska and Hawaii, and in Puerto Rico and other territories, are almost entirely omitted from these calculations. Moreover, the problem of climate change will not end at 2100. Under business as usual, the costs of inaction will continue to mount, more and more rapidly, as time goes on. With rising temperatures there will also be an ever-increasing probability of catastrophic

change, far worse than our estimates of non-catastrophic damages. Collapse of the Greenland ice sheet would lead to sea-level rise of more than 20 feet, destroying coastal communities, industries, and infrastructure everywhere; collapse of the West Antarctic ice sheet would be of a similar magnitude. No one knows exactly at what point this would happen – but everyone knows that ice melts faster as it gets warmer.

In short, the estimates in Table 3 are a very partial accounting for the costs of inaction on climate change. The total costs are uncertain in detail, but are sure to be larger than our estimates.

**Table 3: Costs of Inaction for Four Categories of Damages for the U.S.**

| | *in billions of 2006 dollars* | | | | *as a percentage of GDP* | | | |
|---|---|---|---|---|---|---|---|---|
| | **2025** | **2050** | **2075** | **2100** | **2025** | **2050** | **2075** | **2100** |
| **Hurricane Damages** | | | | | | | | |
| Business-as-Usual | $9 | $40 | $133 | $397 | 0.05% | 0.12% | 0.22% | 0.39% |
| Rapid Stabilization | $1 | $2 | $5 | $12 | 0.00% | 0.01% | 0.01% | 0.01% |
| **Cost of Inaction** | **$9** | **$38** | **$128** | **$385** | **0.04%** | **0.11%** | **0.22%** | **0.38%** |
| **Real Estate Losses** | | | | | | | | |
| Business-as-Usual | $34 | $80 | $173 | $360 | 0.17% | 0.23% | 0.29% | 0.35% |
| Rapid Stabilization | $4 | $10 | $22 | $46 | 0.02% | 0.03% | 0.04% | 0.05% |
| **Cost of Inaction** | **$30** | **$69** | **$151** | **$314** | **0.15%** | **0.20%** | **0.25%** | **0.31%** |
| **Energy Sector Costs** | | | | | | | | |
| Business-as-Usual | $28 | $47 | $82 | $141 | 0.14% | 0.14% | 0.14% | 0.14% |
| Rapid Stabilization | $2 | $3 | $5 | $8 | 0.01% | 0.01% | 0.01% | 0.01% |
| **Cost of Inaction** | **$26** | **$45** | **$77** | **$133** | **0.13%** | **0.13%** | **0.13%** | **0.13%** |
| **Water Costs** | | | | | | | | |
| Business-as-Usual | $200 | $336 | $565 | $950 | 1.00% | 0.98% | 0.95% | 0.93% |
| Rapid Stabilization | $46 | $78 | $131 | $220 | 0.23% | 0.23% | 0.22% | 0.22% |
| **Cost of Inaction** | **$154** | **$258** | **$434** | **$729** | **0.77%** | **0.75%** | **0.73%** | **0.71%** |
| **Total Costs for Four Categories** | | | | | | | | |
| Business-as-Usual | $271 | $503 | $953 | $1,847 | 1.36% | 1.46% | 1.61% | 1.81% |
| Rapid Stabilization | $53 | $93 | $163 | $287 | 0.27% | 0.27% | 0.28% | 0.28% |
| **Cost of Inaction** | **$218** | **$410** | **$790** | **$1,561** | **1.09%** | **1.19%** | **1.33%** | **1.53%** |

***Florida: Higher Risks, Higher Costs***

The costs of climate change, measured as a share of GDP, are lower for the U.S. than the world as a whole. This is because the U.S. is colder than many parts of the world, is better supplied with fresh water, and has an unusually large percentage of population and economic activity in the interior of the country, far from the coastal damages caused by hurricanes and sea-level rise. Yet the U.S., of course, is large and varied; in hotter, water-stressed, and coastal states, nature and geography offer less protection against climate change.

A case in point is Florida, where a currently comfortable climate has led to a booming economy and fast-growing population – and where the risks and the costs of climate change will be much worse than the national average. In an analysis parallel to our national study, we found that a partial accounting of the costs of inaction on climate change could amount to as much as 5 percent of Florida's state income (gross state product, or GSP) by the end of this century. As with the national estimates, this figure excludes many important costs of climate change for which we could not develop meaningful monetary estimates; and all the costs will become larger and larger as temperatures continue to rise beyond 2100.

Our Florida analysis used the same climate projections and the same two scenarios as the national study. Although the temperature changes projected for Florida are slightly smaller than for most other states, they are still important: business as usual will make Florida, on average, 5°F warmer than today in 2050 and 10°F warmer in 2100. The winter, when temperatures are lowest, is currently the most popular time to visit Florida; how much of the state's appeal to visitors and residents will survive an increase in year-round temperatures?

Three of our four categories of national cost estimates could be calculated for Florida; each of them was, unsurprisingly, more serious in the Sunshine State than elsewhere in the nation. The impacts of sea-level rise will be felt all along Florida's lengthy coastline. The calculation of residential real estate losses due to sea-level rise, performed exactly as in the national study, yields a larger percentage of the state economy.

And it is not only residential property that is at risk. Data available for Florida made it possible for us to perform a GIS analysis of the effects of 27 inches of sea level rise – a level that will be reached around 2060 under business as usual. If nothing is done to protect the coastline, 27 inches of sea level rise would put 9 percent of the state's land area, including the homes of 1.5 million people, under water. Of the two counties at the southern tip of the state, Monroe County – including the Keys and most of the Everglades – would lose 99.6 percent of its land area, while Miami-Dade County would lose 70 percent of its area.

Statewide, the facilities at risk from 27 inches of sea level rise include

- 2 nuclear reactors;
- 3 prisons;
- 37 nursing homes;
- 68 hospitals;
- 74 airports;
- 82 low-income housing complexes;
- 115 solid waste disposal sites;
- 140 water treatment facilities;
- 171 assisted livings facilities;
- 247 gas stations
- 277 shopping centers;
- 334 public schools;
- 341 hazardous materials sites, including 5 superfund sites;
- 1,025 churches, synagogues, and mosques;
- 1,362 hotels, motels, and inns;
- and 19,684 historic structures.

Florida's long coastline is also exposed to hurricanes; serious hurricane damages are all too familiar throughout the state. Insurance costs have skyrocketed following major hurricanes in the recent past, forcing the state government to provide expensive subsidies to homeowner insurance. The same method we used to estimate national hurricane damages yields much bigger numbers, as a percentage of the economy, for Florida.

Likewise, the demand for electricity in Florida is strongly correlated with temperature on an hourly basis, reflecting the extensive reliance on air conditioning. On the other hand, there are virtually no heating expenditures to reduce as temperatures rise. As a result, the state's energy costs are projected to rise rapidly, along with the average temperature.

Florida is one of the wettest states in the nation, averaging 54 inches of rainfall annually, and is well supplied with rivers, lakes, and underground aquifers. Nonetheless, heavy agricultural water use for irrigation (both for growing fruits and vegetables during the dry winter months, and for the well-entrenched sugar cane industry), along with rapid residential and commercial development, has led to water shortages in many parts of the state. Florida is already investing in expensive desalination plants to increase water supply – and climate change will make the costs of water supply even higher. However, we were unable to develop a numerical estimate, comparable to our national figure, for climate-related water supply costs in Florida.

We did, however, look at a fourth impact of climate change on the Florida economy: the expected effects on tourism.[8] It is no secret that people from other states and countries like to visit Florida; 10 percent of the state's economy currently depends on tourism, with a seasonal peak in the winter months when the temperatures are lowest. Climate change will mean that winter temperatures will become more like current summer temperatures, while intensified hurricanes and sea-level rise will erode sandy beaches and make the outdoor tourist experience generally less pleasant.

Yet despite the winter peak, Florida has sizeable tourism revenues even in the off seasons, drawn in part by indoor and non-beach-oriented tourist attractions. We projected that by 2100, climate change under the business-as-usual scenario would reduce tourism's role in the Florida economy, throughout the year, to the level of the least attractive season today. That is, by the end of the century, year-round tourism spending in Florida (measured as a percentage of the state economy) would drop to the current level of tourism in the autumn months, or 76 percent as high as the current annual average. Thus we are conservatively projecting only a 24 percent decline in the relative importance of tourism, over a century which includes 45 inches of sea level rise, 10°F hotter temperatures, and more intense hurricanes. It is easy to imagine those business-as-usual climate conditions causing much greater tourism losses.

With our assumptions, the decline in tourism is the largest component of our estimated cost of inaction for Florida. Tourism losses account for about half of the state's cost of inaction; the four areas together reach 5 percent of GSP by 2100, as shown in Table 4.

**Table 4: Costs of Inaction for Florida**

*in billions of 2006 dollars, except percentages*

| | 2025 | 2050 | 2075 | 2100 |
|---|---|---|---|---|
| Tourism | $9 | $40 | $88 | $167 |
| Hurricanes | $6 | $25 | $54 | $104 |
| Electricity | $1 | $5 | $10 | $18 |
| Real Estate | $11 | $23 | $33 | $56 |
| **Summary: Costs of Inaction** | | | | |
| in billions of 2006 dollars | **$27** | **$92** | **$184** | **$345** |
| as percent of Florida GSP | **1.6%** | **2.8%** | **3.9%** | **5.0%** |

[8] We did not create a comparable estimate of tourism losses for the U.S. as a whole because the effect of temperature and other climate changes is less clear over such a large and diverse area: for instance, would Florida's tourism losses result in net national losses, or in offsetting gains to other areas as tourism shifted to other states?

***Maximum Vulnerability: Climate Costs in the Caribbean***

Some parts of the U.S., such as Florida, will face larger climate costs than others. But the worst climate impacts will be experienced in other countries that are uniquely vulnerable to the anticipated changes. Low-lying coastal regions and, above all, small island nations, are most immediately at risk.

In another study of the costs of inaction, we analyzed the expected costs of climate change for 24 island nations and territories in the Caribbean. Data limitations did not allow us to produce an estimate that is strictly consistent with our U.S. and Florida projections.[9] We did, however, estimate three categories of climate damages: increased hurricane damages, infrastructure damages due to sea-level rise, and losses of tourism revenues. The cost of inaction on climate change – the difference between the business-as-usual and rapid stabilization scenarios – amounted to 10 percent of the region's GDP by 2050, and 22 percent by 2100.

While the average impact is large, the costs vary widely from one island to another. The largest, most diversified and least tourism-dependent economies, such as Puerto Rico and Trinidad and Tobago, face lower than average projected damages, as do a few of the smaller islands that lie outside the usual path of hurricanes, or rise well above sea level. On the other hand, greater than average damages are projected for low-lying islands, and those that are frequently struck by hurricanes. Rising sea levels and increased intensity of hurricanes will make some islands unattractive to tourists, if not entirely uninhabitable to the local population. For some islands that are heavily dependent on tourism, the expected losses of visitors and revenues due to climate change will all but destroy the local economy.

Haiti, the poorest nation of the region, is also projected to suffer overwhelming damage to its infrastructure, which it will be unable to afford to replace – a projection that is sadly consistent with that country's experience of recent storm damages. The destruction of some Caribbean economies by climate change will lead to increased migration out of the region, and the United States will be one of the most likely destinations for the new climate refugees. Thus even in the narrowest terms of self-interest (let alone a broader and more reasonable humanitarian perspective), we cannot view the destruction of Caribbean nations by climate change as merely someone else's problem.

[9] The U.S. and Florida projections discussed above include projections of expected growth in population and incomes, based on standard government sources. For the 24 disparate political jurisdictions in the Caribbean study, no such economic and demographic projections were available. Therefore, following the example of an earlier World Bank study of some of the Caribbean islands, we assumed no change in population or per capita income for the region. In cases where projected damages grow at the same rate as GDP, our estimates for damages as a percentage of GDP will remain valid under a range of growth rates.

***Conclusion: We Can't Afford the Costs of Inaction***

There are real costs involved in taking immediate and forceful action to reduce carbon emissions and control the risks of climate change. The best-researched estimates, such as those from Nicholas Stern, or from McKinsey & Company, suggest that roughly one percent of world output needs to be spent on climate mitigation, for some years to come. This is not an amount that should be spent lightly, without careful analysis and planning.

Yet the costs of emission reduction will be a bargain, compared to the high and steadily rising costs of *inaction*. The message of my research, as summarized in this testimony, is that for the United States as a whole, even a partial accounting of the costs of inaction is above one percent of GDP by 2025, and grows steadily worse as time passes and temperatures rise. The most vulnerable parts of the country, such as Florida, face proportionally much greater risks, with a partial accounting of the costs of inaction exceeding five percent of that state's income by the end of this century. Just next door, in the Caribbean, some of the world's most vulnerable nations face more extreme damages, in some cases amounting to near-total destruction of islands and their economies, from the projected business-as-usual climate impacts within this century. This should be viewed by Americans, not just as a loss of exotic vacation opportunities, but as a humanitarian crisis in our backyard, and a likely source of increasing numbers of desperate refugees arriving on our shores.

The bottom line is clear: the cost of taking action to reduce emissions is an offer we can't afford to refuse.

Mr. MARKEY. Thank you very much. I very much appreciate your testimony.

And now we will move to our final witness, who is Dr. Patrick Michaels. Dr. Michaels is a senior fellow of environmental studies at the Cato Institute. He is also a research professor of environmental sciences at the University of Virginia and visiting scientist with the Marshall Institute in Washington, D.C. Thank you for joining, Dr. Michaels. Please proceed with your testimony.

**STATEMENT OF PATRICK J. MICHAELS, SENIOR FELLOW IN ENVIRONMENTAL STUDIES, CATO INSTITUTE**

Mr. MICHAELS. Thank you, Mr. Chairman. I would also like to thank the subcommittee for inviting my testimony on the impacts of climate change. The subcommittee is asking very important questions: what are the implications of climate change for national security, economic development and public health. But before providing informed opinion on the costs of climate change, one must have confident predictions of climate change itself.

[Slide shown.]

On my first slide, if I could, one, proceed from changes in atmospheric composition to changes as modeled by climate models, and then, ultimately, to the impacts. What I would like to examine is what is going on with our climate models. We often hear that the science is settled on global warming. In fact, this is far from the truth. Our models are not, repeat, not simulating global temperature trends in recent decades.

[Slide shown.]

Here I am going to examine in the next slide the ensemble of 21 models used by the United Nations' Intergovernmental Panel on Climate Change for their midrange projection of carbon dioxide emissions, and the world has been going along with this emissions scenario. The changes in concentration in the atmosphere have been very close to these estimates. Note that the behavior of the models is linear. They tend to predict a constant rate of warming. This is from 2000 to 2020. The individual models vary quite a bit from model to model and in fact some models can even have cooling trends in them for certain periods of time.

[Slide shown.]

The next slide shows the observed temperatures since the second warming of the 20th century started in the late 1970s. One of the things that you see is it actually too is constant, despite this much talked of peak in 1998, which is clearly a high point in the record as a result of solar activity, in addition to an El Nino and pressure from greenhouse warming.

Now, what I am going to do is, I am going to give us the range of predictions from each model, next slide. From all 21 models, I ran them for various periods of time, 5-year trends, 6-year trends, 7 years and out to 15-year trends. The bottom line is the 2nd percentile of warming. The top line is the 97.5 percentile. So this is the 95 percent confidence range in the climate models, and the solid black line are the observed temperature trends for the last 5 years, 6 years, 7 years, et cetera, on out to 15 years. You can see that they are running at or below the bottom limit of the model's confidence. This is not very good, and unfortunately tells us that

we are undergoing a systematic failure of our midrange models in recent decades.

[Slide shown.]

The next slide shows what happens as this persists. Assume that the temperatures in 2009 globally are the same as the average for 2008. That is a reasonable assumption because we are in what is called a La Nina, which is a relatively cool period, and the addition of yet another year to these 15-year trends gives you everything below the 95 percent confidence level. It is very unfortunate but it tells us a lot that we need to do. Now, everybody knows that the behavior of the last 10, 12 years seems to be a bit unusual, so let us extend this analysis in the next slide to the last 20 years, if we could. That would be in the next image. There you go.

[Slide shown.]

We have to take out the effect of Mt. Pinatubo, which occurred in 1991 and introduced a cooling at the beginning of the record so there was a rapid warming that was induced that biases that record. The models themselves do not have volcanoes in them so an apples-to-apples comparison takes that out and you can see again that the observed temperature range, now with trends on out from 14 to 20 years, is falling below the 95 percent confidence level. What do we say? One implicit assumption about calculating the costs of inaction is that we know that reasonable confidence with the climate change will ensue as carbon dioxide accumulates in the atmosphere. This demonstration shows that oft-repeated mantra in Washington, "The science is settled" is not true at all. More important, the rates of warming on multiple time scales are invalidating the midrange sweep of IPCC models.

This is a problem that has received very little attention but it is very germane to this committee. Until we know, until we have models that in fact accommodate the behavior of recent decades, we appear to be overestimating the rate of climate change. As you can see, it is all at the lower end, where the observations are. If climate change is overestimated, then so are the impacts of that change, and that is something we must pay attention to as we address this issue. Thank you very much.

[The prepared statement of Mr. Michaels follows:]

TESTIMONY OF PATRICK J. MICHAELS TO THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT OF THE COMMITTEE ON ENERGY AND COMMERCE, U.S. HOUSE OF REPRESENTATIVES.

Senior Fellow in Environmental Studies
Cato Institute
Washington, DC

Research Professor of Environmental Sciences
University of Virginia
Charlottesville, VA

The following testimony represents no official position of the Cato Institute or the University of Virginia and is tendered as an individual statement under the tradition of academic freedom.

**********

This Subcommittee asks important questions: What are implications of climate change for national security, economic development and public health?

The answers to the important questions about the implications of climate change are driven by a series of computer models and mathematical simulations. First, one estimates changes in climate. Then these changes are input into a series of subsidiary models to estimate their impact. Finally, one compares putative costs of the climate change compared to the costs of mitigation by reduction or stabilization of the concentration of atmospheric carbon dioxide.

We often hear that "the science is settled" on global warming. This is hardly the case. While almost all scientists agree that global surface temperature is warmer than it was a century ago, there is considerable debate about the ultimate magnitude of warming, as evinced by the broad range of future mean surface temperature given by the United Nations' Intergovernmental Panel on Climate Change.

The primary drivers of the impact models are therefore the models for climate change itself. I must report that our models are in the process of failing. When I say that, I mean the ensemble of 21 models used in the midrange projection for climate change by the IPCC. I am an active participant on this Panel, providing extensive reviews and comment on several iterations of their scientific summaries, as well as invited text for their Second Assessment.

If it is demonstrable that these models have failed, then there is no real scientific basis for any estimates of the costs of inaction. I will now perform that demonstration.

Remember this: a climate model is really nothing more than a scientific hypothesis. If a hypothesis is consistent with observations, then it is standard scientific practice to say that such a hypothesis can continue to be entertained. In this case, that hypothesis can then serve as a basis for other subsidiary models or, in reality, subsidiary hypotheses.

If the hypothesis is not consistent with observations, it must be rejected. That does *not* mean that human-induced climate change may or may not be real, but it does mean that (in this case) the magnitude of prospective change has—with high probability—been overestimated. That means that all subsidiary hypotheses on economic costs, strategic implications, or effects on health are similarly overestimated.

Figure 1 shows the various model projections for the IPCC "A1B" emissions scenario for the period 2000-2020. This is the "midrange" estimate. Actual emissions rates that are above these values will produce higher projected rates of warming, and vice-versa for lower ones. The actual accumulation of carbon dioxide in the atmosphere, in parts per million, has been very close to the A1B estimates, so it serves as a very useful point of analysis.

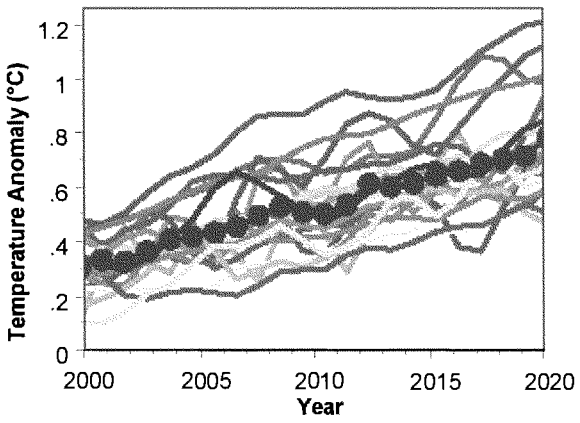


**Figure 1. Climate model projections (colored lines) and climate model ensemble mean (black circles) of global average surface temperature anomalies, 2000-2020, under the IPCC A1B emissions scenario.**

Figure 2 shows the observed surface temperatures from the University of East Anglia record since the second warming of the 20th century commenced in 1977. This history, designated HadCru3, and its predecessor versions, are the most cited histories by the IPCC. For designation, I refer to this as the IPCC surface data hereafter in this testimony.

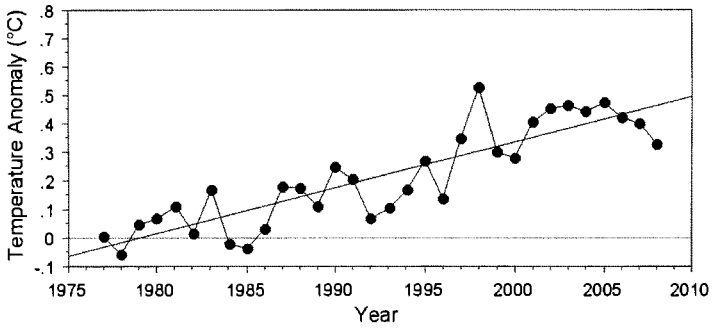


**Figure 2. Annual global average temperature anomalies, 1977-2008, from the HadCru3 temperature history.**

Several things should be apparent.

First, the ensemble behavior of the A1B models is largely linear in this time frame. In other words, the tendency of both the individual models (colored lines) and the average of the models is a constant rate of warming. Indeed, the observed warming in the HadCru3 record, back to 1977 (when the second warming of the 20th century commences) is also constant. This is true despite a lack of overall trend since 1998, but it is noteworthy that 1998 was an obvious high point in the observed record because of a strong El Nino and an active sun, in addition to the warming pressure from increasing carbon dioxide.

We now examine the distribution of warming trends within the 21 A1B models for various time periods. We use the set of models available at http://climexp.knmi.nl/, a standard reference. The models begin in 2001 and end in 2020. Note that the modeled warming rates in the first half of this period, which we are nearly through (by 2010), are the same as they are in the second half. In other words, the modeled rate of warming is constant.

We first analyze various modeled trends beginning with a five-year window and then on up to 15 years, using the 2001-2020 reference period. We ran successive monthly iterations of each model. Consequently the sample size is very, very large. The results are shown in Figure 3.

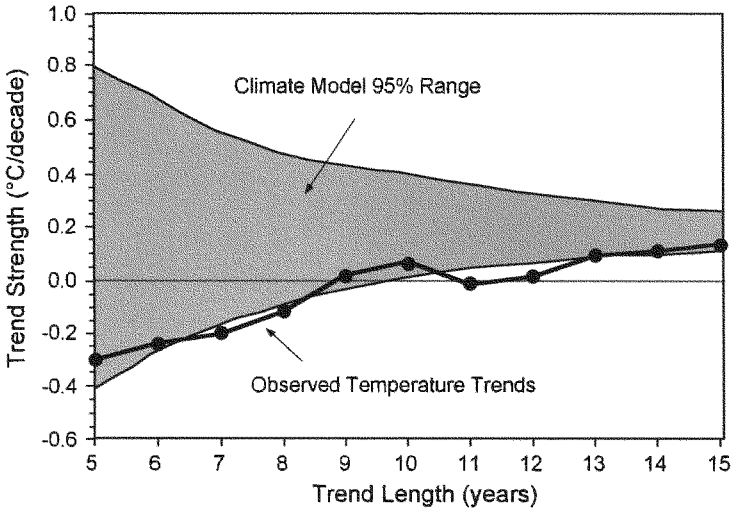


**Figure 3. Climate model 95% confidence range of projected surface temperature trends of varying lengths (gray area) and the current observed values for these trends (through December 2008) (black line).**

We then calculated the percentile ranges of temperature change for the model ensembles at the .025 level on both the "warm" and "cold" sides of the model distributions. This is analogous to the 95% confidence bounds for the model ensemble. Generally speaking, hypotheses are either rejected or continued to be entertained at the .95 level, so our test of the models is consistent with normal scientific practice.

Also in Figure 3 are the observed temperature trends for periods from five to fifteen years from the IPCC history, ending in December, 2008. It is very clear that temperatures are running at the lower limit for the .95 confidence level. In other words, the ensemble of the AIB models is *failing*.

While much ado has been made about the lack of warming from 1998 through now, the analysis is clearly quite stable across other trend periods. However, the longer that the current regime persists, the worse the models fail. Figure 4 assumes that 2009 mean surface temperatures are the same as 2008, which is a very reasonable assumption at this time. We are currently in the cold phase of El Nino, called La Nina, which decreases the likelihood that this will be a very warm year.

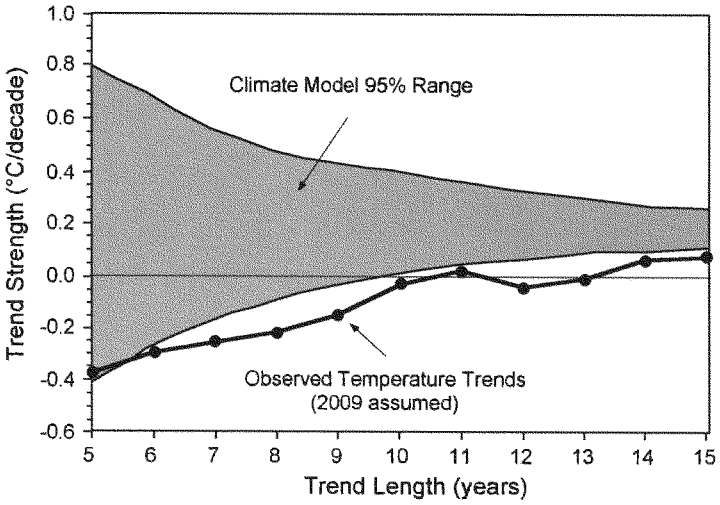


**Figure 4. Climate model 95% confidence range of projected surface temperature trends of varying lengths (gray area) and the expected values for these trends assuming the temperature in the coming year is similar to the temperature in 2008 (black line).**

In Figure 5, we run the analysis for the last 20 years of observed IPCC temperatures (1989-2008), rather than the last 15. There is a clear warming trend in this period, but, again, it is so low as to fall again along the .95 level. The ensemble model failure is not a product of the selection of recent years; rather it is a systematic failure of the models as a whole to accommodate temperatures in recent decades.

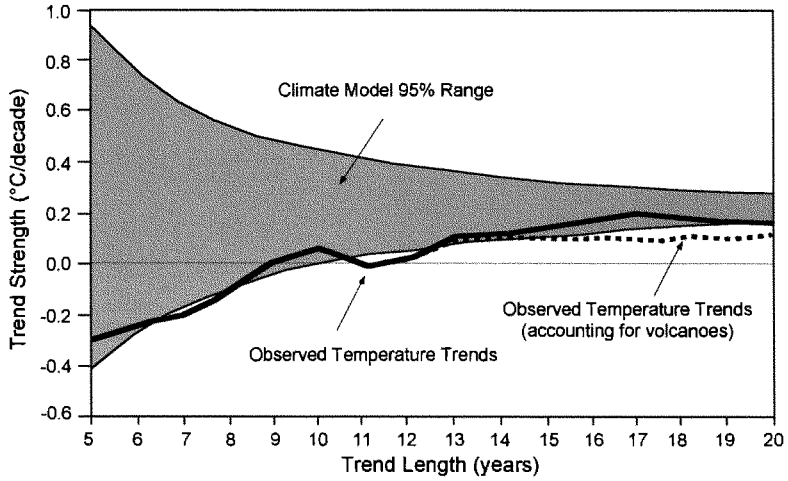


**Figure 5. Climate model 95% confidence range of projected surface temperature trends of varying lengths (gray area) and the current observed values for these trends (through December 2008) (thick black line) and when the observations are adjusted to account for the impact of Mt. Pinatubo (dotted black line).**

The failure becomes even more obvious when the effect of the 1991 eruption of Mt. Pinatubo is removed. This results in a more appropriate comparison of the model ensemble with observations because the models themselves contain no volcanoes. Being near the beginning of the 20-year analysis period, Pinatubo introduced a temporary cooling early in the study, which results in more "apparent" warming than was observed. As a consequence of this adjustment, the observed temperature trends fall away from the .95 level for trends of 15 to 20 years in length.

**"The Science is Settled"?**

One implicit assumption in calculating the "costs of inaction" is that we know with reasonable confidence indeed what climatic changes will ensue as atmospheric carbon dioxide concentrations increase. With regard to climate, we often assume a common Washington mantra: with regard to global warming, "the science is settled".

This demonstration shows how far from the truth this oft-repeated sentence actually is. One can say this. "The science is settled" inasmuch as surface temperatures have increased from the late 1970s. That this is shown in the surface record has not been in dispute, so claiming some finality for such a truism is hardly noteworthy. What is true, however, is that the rates of warming, on multiple time scales, have now invalidated the midrange suite of IPCC climate models. No, the science is *not* settled. In fact, judging from these results, it's time for climate scientists to get back to work and generate models

which will be able to estimate the recent past and present within their normal confidence ranges.

Until that is done, all we know is this: calculations of the costs of inaction, based upon models that are clearly overestimating warming to the point that they can no longer be relied upon, are likely to be similarly overestimated. In that eventuality, the costs of drastic action can easily outweigh the costs of a more measured response, consistent with what is being observed, rather than what is being erroneously modeled.

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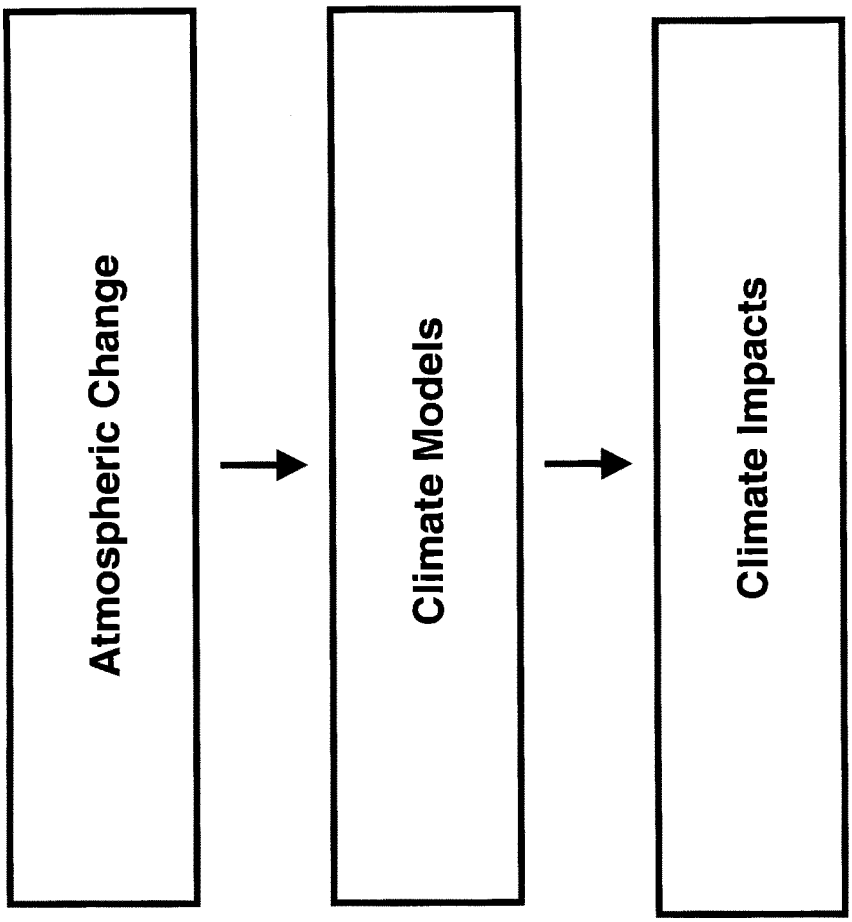
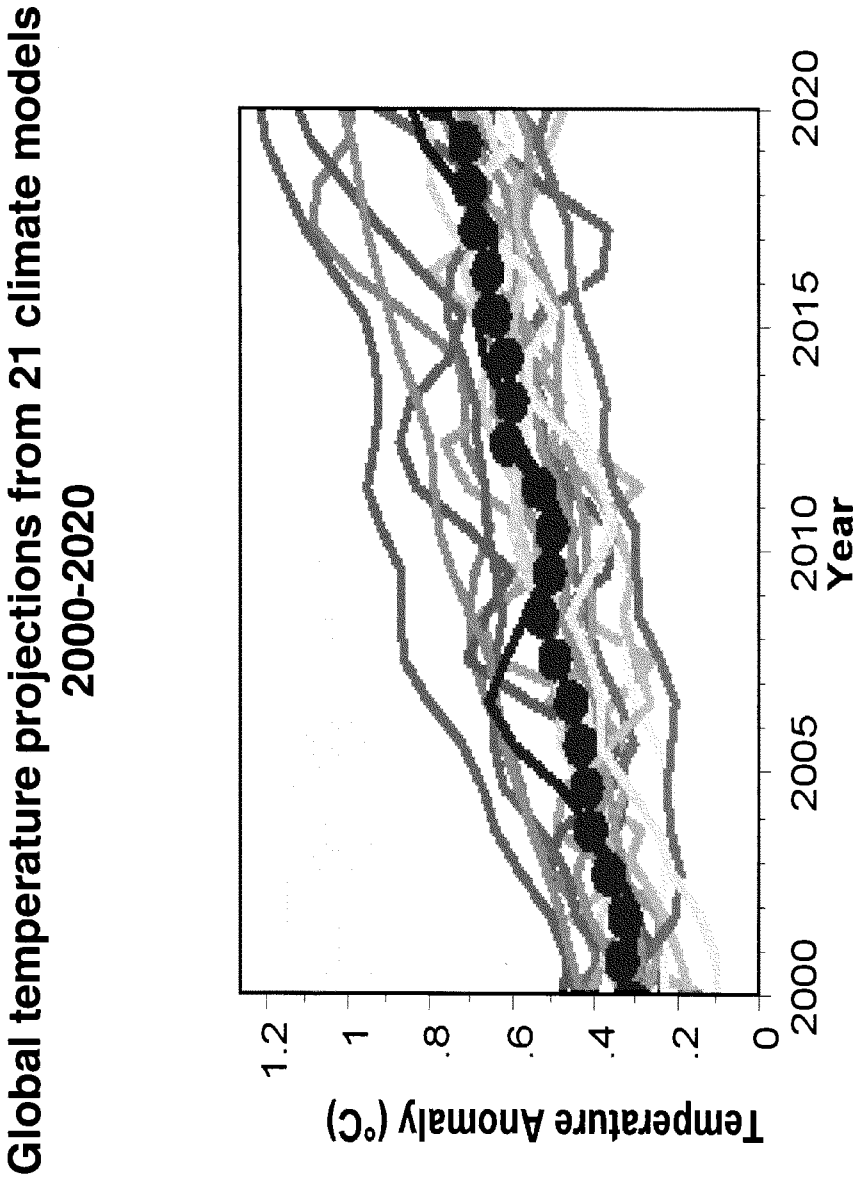
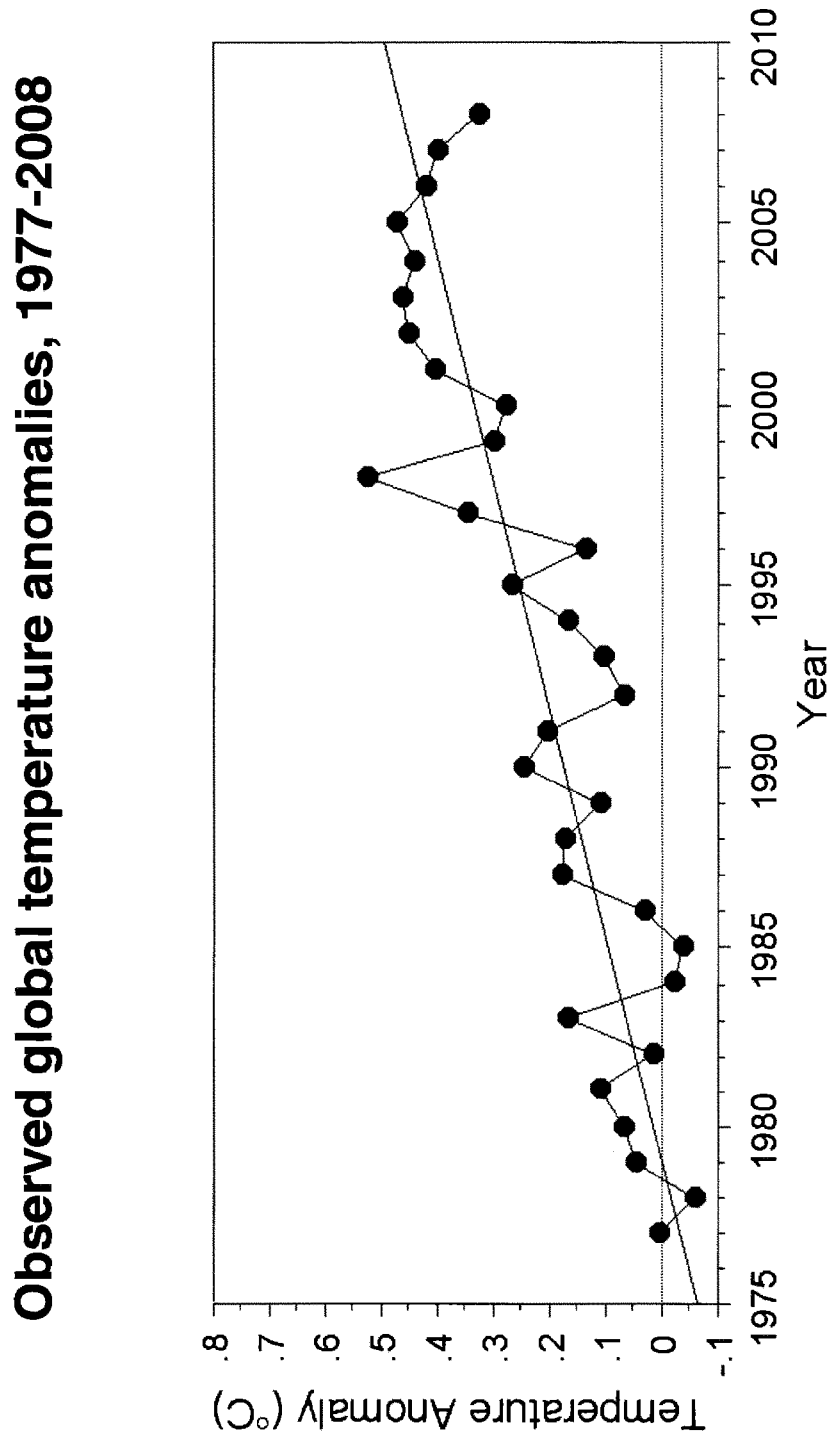
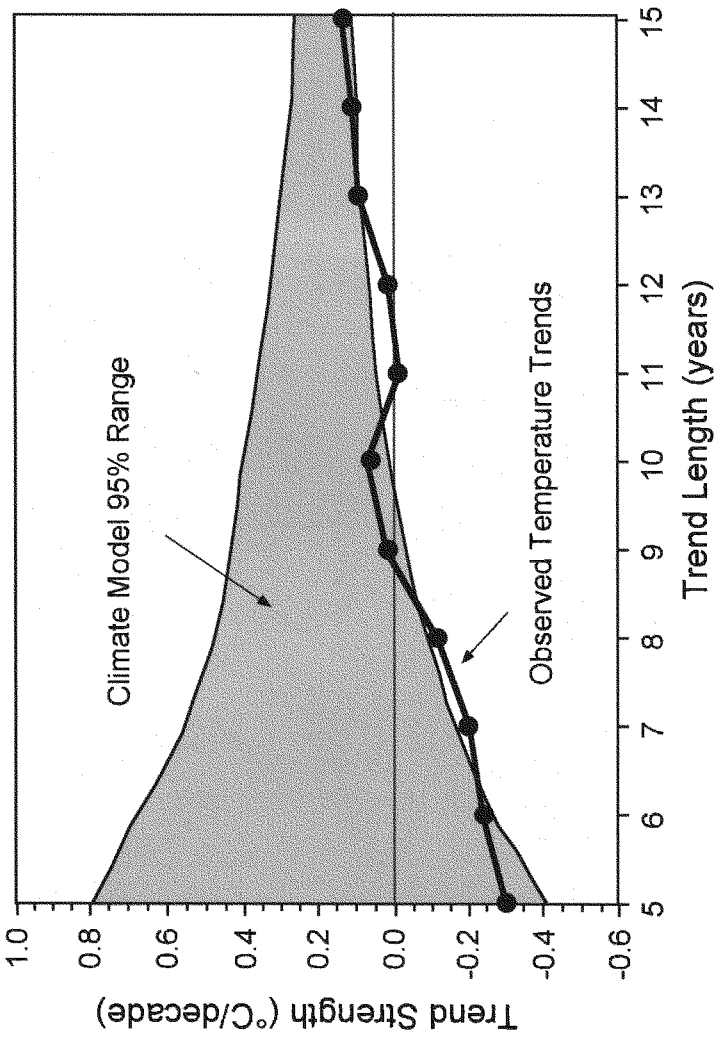

Atmospheric Change
Climate Models
Climate Impacts

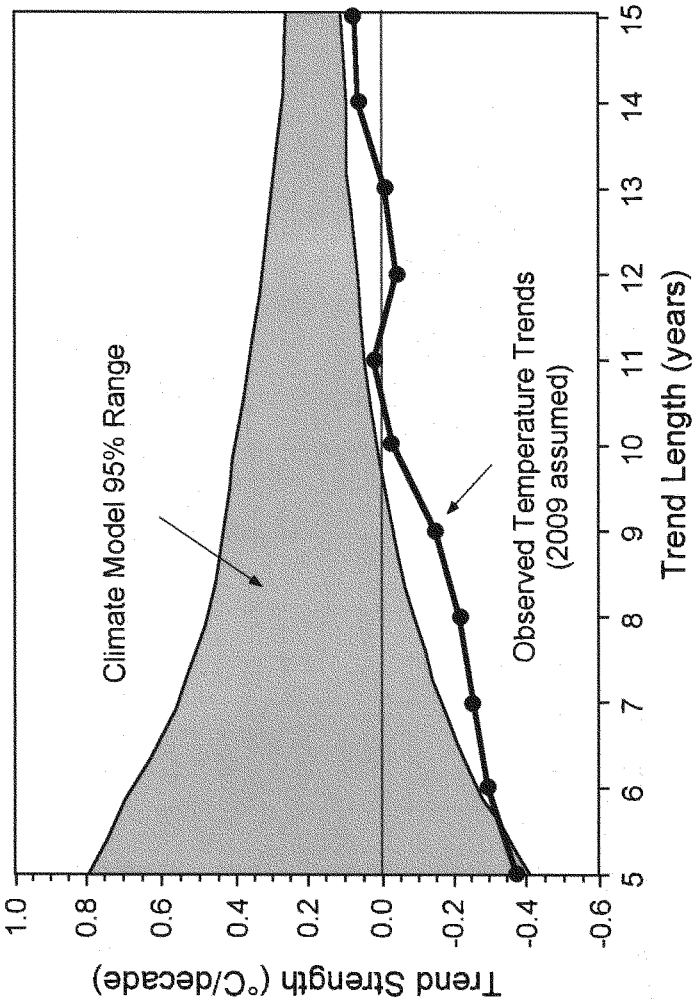

Global temperature projections from 21 climate models
2000-2020
Temperature Anomaly (°C)
1.2
1
.8
.6
.4
.2
0
2000
2005
2010
2015
2020
Year


Observed global temperature anomalies, 1977-2008
Temperature Anomaly (°C)
.8
.7
.6
.5
.4
.3
.2
.1
0
-.1
1975
1980
1985
1990
1995
2000
2005
2010
Year

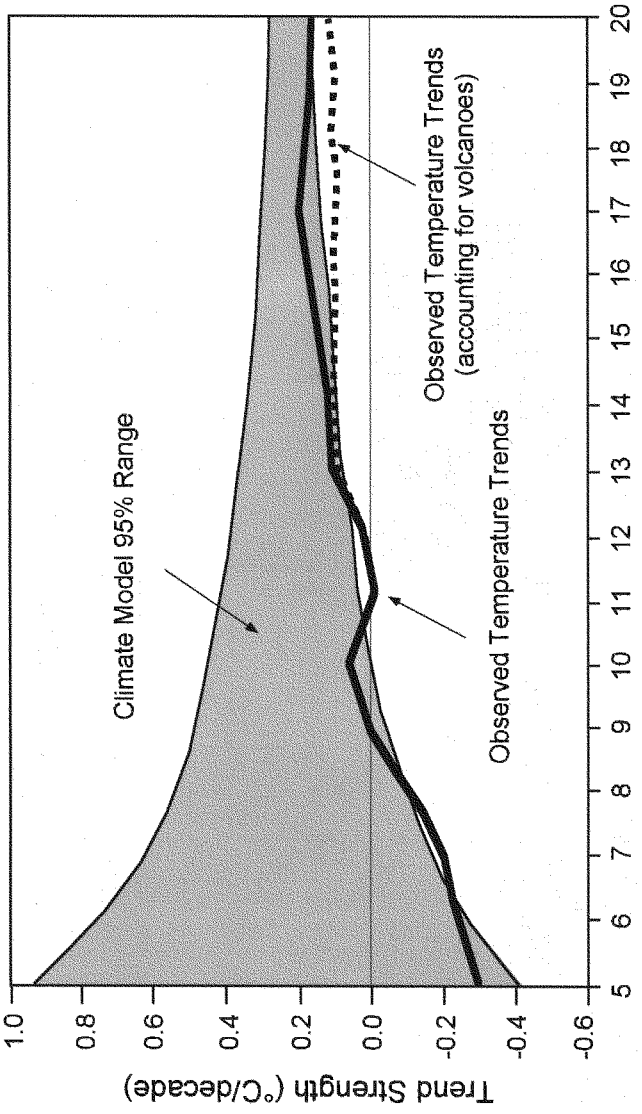
**Comparison of Model Projections and Observed Temperature Trends**



**Comparison of Model Projections and Observed Temperature Trends**
**(assuming 2009 to be the same as 2008)**



**Comparison of Model Projections and Observed Temperature Trends**
**(with and without the influence of volcanoes)**



Mr. MARKEY. Thank you, Dr. Michaels, very much. The chair will now recognize himself for 5 minutes for a round of questioning.

Professor Schrag, you just heard what Dr. Michaels said. He is basically saying we just shouldn't worry as much about global warming because it is not going to be as bad as the models predicted. Your quick response to that?

Mr. SCHRAG. Well, I think it flies in the face of all of our knowledge, both about earth history—we can actually get a very good sense of the sensitivity of the earth's climate to changes in carbon dioxide from looking at the past over various time scales, over ice ages, or even back millions and tens of millions of years, and the general answer we get is in fact that the models tend to be less sensitive than the real world. It is very clear from that estimate that in fact we are in for bigger trouble.

Looking at the last 2 decades is a very tricky thing, what Dr. Michaels was talking about, simply because we also have sulfate aerosols that we are putting out from burning a lot of coal, especially now that China is burning so much coal and putting sulfur dioxide into the air. That counteracts the effect of $CO_2$, and because we don't know that number very well, it means that we don't understand the rate of forcing perfectly, but it would be a deep mistake to think that that should give us comfort. In fact, the opposite conclusion is the case. If in fact temperature has not warmed as much because of sulfur emissions, sulfur doesn't last in the atmosphere very long, whereas carbon dioxide lasts for hundreds of years and that means we are in for a big shock in the decades ahead.

Mr. MARKEY. Thank you, Professor Schrag.

General Sullivan, you were Army Chief of Staff back in the early 1990s and I know you had decisions to make about Somalia at that time and the events that ultimately led to "Blackhawk Down," the movie. Could you talk a little bit about climate change, Somalia, Darfur, that whole region in terms of how, as a military group, you were analyzing the climate change data?

General SULLIVAN. Well, as you stated, Somalia, Darfur, that part of Africa has been buffeted by drought for years. The drought enabled, frankly, the warlords to start controlling food aid that was going in. They were controlling the food, selling the food to their people. That created the deaths of other tribes that weren't supported by the warlords, which created instability and it enabled, frankly, Somalia to move on to where it is a failed state now, and as we all know, you now have privates operating out of Darfur, which are destabilizing the Gulf of Aden and the Red Sea. It is all related to the same thing which is going on in Darfur, where you have migratory farmers, herders superimposing themselves on the top of farmers and it is a vicious cycle.

Mr. MARKEY. And you relate this to drought that leads to famine ultimately caused by this climate change phenomenon?

General SULLIVAN. Absolutely we can, and when we see the Himalayas, as was mentioned by Dr. Schrag, when we think about the water loss there, you can see the same picture in Bangladesh, India, Pakistan, and elsewhere, not to mention, by the way, Israel, Jordan, the Palestinians. The water in that part of the world comes from the Jordan River, and it is all related.

Mr. MARKEY. Thank you, General Sullivan.

Mr. Woolsey, could you expand upon General Sullivan's point with regard to the national security implications for our country if we see deterioration because of climate change in these regions of the world?

Mr. WOOLSEY. Mr. Chairman, it can hit us very close to home. One of the fastest set of melting glaciers is apparently in the Andes, and if we think we have trouble coming up with a sound and agreed-upon immigration policy for the United States now, what is it going to be like if our southern borders are seeing millions of our hungry and thirsty southern neighbors headed toward temperate climates? Also, from the point of view of our being able to ameliorate some of the terrible events from weather pattern changes and so forth, such as the U.S. armed forces did, particularly the Navy, so well in response to the tsunami in Indonesia a few years ago, it is going to be very difficult for any country, even us, to shoulder much of a humanitarian burden if we are seeing direct and immediate effects that we have to deal with that stress our own systems here.

I chaired the policy panel for a defense science board study last year that was chaired by former Secretary of Defense Schlesinger, and our report called "More Fight, Less Fuel" is on the defense science board Web site. It might be worth the committee having a look at because it talks about the interaction of energy policies and the capabilities of the armed forces, and there is a classified annex, which the committee certainly can have access to, I am sure, through the Defense Department, and I can tell the staff about that.

Mr. MARKEY. And Mr. Woolsey, you would recommend that the members see that classified annex because it does relate to climate change and it impact on——

Mr. WOOLSEY. It does.

Mr. MARKEY [continuing]. National security?

Mr. WOOLSEY. It relates principally to specific vulnerabilities of our military as a result of things like electricity grid vulnerability.

Mr. MARKEY. My time has expired.

Mr. WOOLSEY. But that is one of the subjects, but the classified part deals mainly with that.

Mr. MARKEY. Thank you, Mr. Woolsey.

The chair recognizes the gentleman from Michigan, Mr. Upton.

Mr. UPTON. Thank you, Mr. Chairman, and I want to make a couple of comments and get the reaction from you all. First of all, General Sullivan, your statement, energy alternatives to reduce reliance on fossil fuels needs to be a priority, is one that I think most of us share, and I appreciated that.

Admiral Woolsey, we have had some briefings, I guess you could say, in the last year about the vulnerability of our grid and what terrorists might be able to do, and I would hope that if this stimulus package passes, that some of those concerns can be addressed in terms of the smart grid. Maybe that is something that we need to have a hearing on at some point later this year. It came to a head last year with Chairman Boucher.

Mr. MARKEY. We will do that.

Mr. UPTON. But I would like to just make a couple of comments. We haven't done just nothing. In my view, we have actually done

a lot, and Dr. Ackerman, you shouldn't be embarrassed by the lack of activity when you look at the progress that our country has made. Until this year, we have had a growing economy, growing population, and we have tried to figure out how we are going to be prepared by the year 2030, when our electricity use is expected to go up as much as 40 to 50 percent. We have done a lot on conservation. We are focused on renewables. A number of States, including mine, now have an RFS standard. Texas is another State that has done the same thing. With maybe the exception of Nantucket, we are actually doing something about wind but we will deal with that Massachusetts issue another day. Nuclear has been to me, I have been embarrassed. I have been embarrassed about the lack of progress on nuclear, that we haven't actually turned that switch back to green after 20-some years. We made progress on autos. I know the chairman and I were both at the auto show here in D.C. this last week, and it is amazing to see some of the new cars that are going to be in the showroom not only this year but in the future and you look at some of the electric hybrids that the Big Three are developing, all to be in the showroom by some time next year.

We have seen great strides on appliance standards, building standards, Jane Harman, my colleague, on light bulbs, who is here, those kick in within a couple years and we are going to save tons of carbon from being emitted into the atmosphere, and it was something that we worked on together.

FutureGen, I think there is money in the stimulus package for FutureGen, and I hope that that works. I am a very strong supporter of clean coal, and I would say that we are probably doing more as a Nation on carbon capture than just about anything else. In the hearing that we had with U.S. CAP a couple weeks ago, you know, they are hoping by 2015 we are going to have an answer. Again, we are the leaders on that technology.

And when you look at that, since 2002, despite, you know, we have had a growing economy, our greenhouse gas intensity has actually fallen by an average of about 2 percent per year from the year 2002 to 2007. When you counter that with what has happened in the E.U., it came up with a scheme, as Mr. Gore would say, on cap and trade and their emissions have actually gone up, not gone down. So our concern, when you look at these statistics, the United States emits about 5½ billion tons of energy based on $CO_2$ each year. The developing world does 14 billion tons, almost three times as much. By 2030, we are going to increase allegedly by about 2 billion tons annually but again the developing world is going to go up by another 12.8 billion, or six times what we are expecting to do. Now, we need incentives for clean energy. I think we can do it. We need to be on that path, but what happens if the developing countries, China and India, China now the world's largest emitter, what if they don't follow that track? My State is so hard hit, we are devastating by the job losses and our economy is just totally in the tank, and I can just see that this will be yet another incentive for those jobs and economic opportunities to go someplace else.

I don't know who would like to respond to that but I wouldn't be embarrassed. I think we have been on a road of progress, and I look forward to continuing that road of progress, to have the incentive to actually see us get to the conclusion that certainly Gen-

eral Sullivan would like us to see. In my remaining time, who would like to respond?

Mr. MARKEY. The gentleman has 2 seconds left for the panel to answer. We will give one person down here a chance to respond.

Mr. WOOLSEY. First of all, Congressman Upton, thanks for the promotion but I never got above captain——

Mr. UPTON. All right. I am sorry.

Mr. WOOLSEY [continuing]. In General Sullivan's organization, the Army. I think you make a good point. In our own way, we have made some progress in a number of these areas but we haven't always chosen the most effective way to do it. For example, the renewable portfolio standard has some positive features but you get just as much credit for moving away from natural gas to renewables as you do moving away from coal, whereas if you had a feed-in tariff, you would have a lot more incentive, I think, to move, not only for large facilities like, say, solar power plants and wind farms but also to distribute it a generation. I think it is a far superior mechanism. The Germans have shown how well it works in Germany. So we haven't really picked, I think, in many circumstances the mechanisms that can move us quickly, and I agree with you very much about plug-in hybrids. I drive one myself, and the infrastructure I picked up at Walmart for $14.95. It is an orange extension cord, and that is all the new infrastructure you need for a plug-in. It is a pretty good deal.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Utah, Mr. Matheson.

Mr. MATHESON. Thank you, Mr. Chairman.

Professor Schrag, one of the issues that Congress is going to have to deal with if it puts together a cap-and-trade bill is setting the targets from year to year and what the shape of the curve is going to be over time, and the panel today has talked about a sense of urgency about wanting to take action, and I think you have heard a lot of folks, Members of Congress, also acknowledge that sense of urgency. But we have got this challenge because there are certain technologies out there that are not at the level of maturity that we would like them to be for us to have real certainty about our ability, whether it is carbon capture and sequestration, whether it is alternative fuels, cellulosic ethanol, whatnot, so I wondered if you could talk to me for a bit about your thoughts about what the shape of the curve should be. If you don't know what specifically what the shape is, how should we decide what those targets should be from year to year?

Mr. SCHRAG. I think that is a very good question. I think that there clearly there needs to be, and economists and scientists would both agree, that there clearly needs to be a price on carbon, but putting a price on carbon too quickly too high would have a bad effect because, as you said, some of the major technologies that are going to be necessary to meet these challenges aren't really demonstrated yet, and what that means in practical terms is that banks and financial institutions aren't willing to invest in those projects.

So I think there is a two-prolonged approach. One is, I think through the stimulus package and additional things that this Congress will do over the next 2 years, we need to see government sup-

port, perhaps loan guarantees, for getting some number, a dozen, 10, 20 major projects in these categories, carbon capture and storage, synthetic fuels that are clean, that are low carbon and are capital intensive, and we need to demonstrate to the market that these technologies can work. Find out what works and find out what doesn't work and find out what it really costs. We need to build some nuclear plants and figure out what they really cost. But it is also very important in setting the price on carbon through a cap and trade or whatever additional mechanisms are used by this Congress that you forecast to the market that the long-term price is going to rise because unless that is done, you won't get the right type of investment in technology. It is very important that I think you start out with a low price that doesn't really hurt our industry in the short run, but in the long run that price has to rise and we have to forecast that it will rise.

My final point is the concern that the Congressman from Michigan and many others have expressed of loss of jobs overseas. It is a very serious issue. I actually think the best way to get China and India engaged is to take a start and focus on the technologies that will apply to their economies, and there are some trade issues that we could deal with, like a non-discriminatory tariff that would level the playing field, much more easier to enforce if we got together with the E.U. and then went to China and India and talked. I think those are very interesting ideas that need to be explored.

Mr. MATHESON. I think your ideas have merit but I have to say, it also still points out this challenge that we have of, you have talked about the notion of perhaps government-sponsored efforts to encourage how we learn about these technologies over the next couple years and yet we are talking about moving a bill this year that is going to set these cap levels and these targets year by year. But we won't have that information yet in the next 2 or 3 years or however long it is going to take to develop those technologies, and I don't know if I am asking you another question or just pointing out the challenge I think we face here in terms of trying to get this right.

Mr. SCHRAG. I think that the low-hanging fruit in all of this is energy efficiency. It is probably negative cost, or at least it is not extremely expensive. It makes us leaner and more competitive around the world, and I think the initial impact of a low price on carbon through a cap-and-trade bill is going to be a huge investment in energy efficiency and that is great for the U.S. economy and its competitiveness. Some of the bigger, deeper cuts down the road as the cap tightens in the future will come from these other technologies and that means separate from the cap and trade. We have to get some of these technologies built, not just at a demonstration scale, but at a real commercial scale so we can see what happens.

Mr. MATHESON. Mr. Woolsey, you mentioned the last time about the feed-in tariff in Germany. Could you explain that a little more to the committee right now?

Mr. WOOLSEY. Yes, I will say very briefly, Congressman Inslee has forgotten more about that issue than I will ever know so he is one of the resident experts up here but the Germans came up with this mechanism, and it has been adopted in a number of other

countries to guarantee a reasonable price for generation of renewables that one has a right to whether one is a small rooftop generator, photovoltaics on the roof of the farmhouse like I have on mine or whether one sets up a large number of solar panels, let us say, in a retirement complex for hundreds of homes. In most of the United States, the utilities and the public utility commissions have a mindset that the way to produce electricity is to build big power plants and string transmission lines and distribution lines. They have been doing that for well over a century. They know how to do it and these are the policies they implement. What a feed-in tariff does is say if you are doing renewables, you can get paid a reasonable price by the utility in order to send back to the grid a certain amount of renewable power, and it may be a relative large amount if you are a small corporation, or it may be a small amount if you are a household. In much of the United States, you can do what we do at our farm. You can run your meter backwards to zero by having photovoltaics on the roof, but you can't make money, and the Germans have figured out, I think better than anybody else, how to incentivize renewables with a relatively simple process. It is easier for them because they have—our electricity is largely done State by State, not everything, but a lot, but that is a broad outline of the issue.

Mr. MATHESON. I appreciate it.

Thank you, Mr. Chairman. I yield back.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Kentucky, Mr. Whitfield. I am sorry. I did not see the gentleman. The chair, with the indulgence of Mr. Whitfield, will recognize the ranking member of the full committee, Mr. Barton.

Mr. BARTON. Thank you, Mr. Chairman. I am such a shrinking violet, it is easy to overlook me.

I want to start out with Dr. Michaels by complimenting you on being here, and I want the record to show that the rules of the committee ostensibly require that there be two Minority witnesses, or a third of the witnesses be Minority, which if you take six witnesses, we should have two Minority, but Dr. Michaels is our only one, so it is five to one, which we appreciate you being the one, Dr. Michaels, for showing up.

Mr. HALL. Would the gentleman yield?

Mr. BARTON. I will at the end of my time if we can get a little extra time.

Mr. HALL. I may forget what I am going to ask you by that time.

Mr. BARTON. All right. I will yield. I only have 4 minutes.

Mr. HALL. I just wondered if you knew that the chairman had four, and when he found out Dr. Michaels was really going to be here, that he added Professor Schrag and made it—it must really say something for Dr. Michaels.

Mr. BARTON. That is one way to——

Mr. HALL. I yield back my time.

Mr. BARTON. Anyway, Dr. Michaels, you are an active official of the U.N. Intergovernmental Panel on Climate Change. Is that not correct?

Mr. MICHAELS. Yes.

Mr. BARTON. OK. So you are not some out in right field guy who is just observing, you are active in the participation of the IPCC?

Mr. MICHAELS. Yes.

Mr. BARTON. These models that you refer to in your testimony, for lack of a better term, they are the official models of the U.N.?

Mr. MICHAELS. The U.N. uses three suites of models that they concentrate on in their latest report. The one I looked at was the midrange suite because that is the one at which the concentrations of $CO_2$ that are in the atmosphere resembles the most.

Mr. BARTON. But these aren't models sponsored by Exxon-Mobile or——

Mr. MICHAELS. No.

Mr. BARTON. These are the official U.N.——

Mr. MICHAELS. There are——

Mr. BARTON [continuing]. Subset of——

Mr. MICHAELS [continuing]. Twenty-one different models that they use.

Mr. BARTON. OK. Now, I'm going to read from your testimony, or at least paraphrase from your testimony. We often hear that the science is settled on global warming. This is hardly the case. There is considerable debate about the ultimate magnitude of warming. I must report that our models are in the process of failing. When I say that, I mean that the ensemble of 21 models used in the midrange projection for climate change for the IPCC. If it is demonstrable that these models have failed, then there is no real scientific basis for any estimates of the cost of inaction. Now, why do you say that the models are failing? And again, these are the official U.N. climate change models. These aren't some business-sponsored, anti-climate change models, these are the ones that everybody is basing their so-called projections on. Why do you say they are failing?

Mr. MICHAELS. What I did is, I looked at the range of projections made by these models and I looked at them for multiple, multiple iterations. For example, I used 20 years of models and for 5-year projection ranges, I moved forward 1 month beginning at 60 months and then 1 plus 61, etc. It was a very, very large sample size that can give you the distribution of warming rates for different lengths in time predicted by the models and then you can compare that to the observed warming rates for the last 5 years, for the last 10 years, for the last 15 years and the last 20 years, and what you see is that the observed temperatures fall along or below the 95 percent confidence limit for the model.

Mr. BARTON. So they fail because they don't predict the——

Mr. MICHAELS. They predict too much warming, and if you take a look at the systematic behavior of the models, which is very interesting, they generally predict constant ranges of warming, not increasing rates of warming, and in fact, the rate of warming since 1977 does correspond to a constant rate. It just happens to be right at the lower limit of the rates that are given by the families of models. That tells me something. Nature has been responding to carbon dioxide for decades, and maybe we ought to listen to nature rather than to computers.

Mr. BARTON. Dr. Schrag showed a chart early in his presentation that shows the last 650,000 years of temperature as far as we

know it and it shows it going up and down, up and down, up and down. For most of that time period there were no human beings as we know them today on the earth, so what caused the rapid increase in temperature those previous times since there were men around?

Mr. MICHAELS. Well, these are the Ice Age oscillations that you see in these ice core records. Those were caused by earth orbital changes, we think. That is the current myth. That myth is ultimately subject to——

Mr. BARTON. But it obviously couldn't have been caused by man-made $CO_2$?

Mr. MICHAELS. It was not caused by carbon dioxide, no.

Mr. BARTON. Mr. Chairman, could I have one more question?

Mr. MARKEY. Yes.

Mr. BARTON. I know my time has expired.

Mr. MARKEY. Of course.

Mr. BARTON. Dr. Michaels, I am told that in these core samples and the pinecone samples and all of those data sets that it appears that the temperature goes up before the $CO_2$ concentrations go up by a time period somewhere between 100 to 800 years. So in other words, the dominant variable is temperature and the dependent variable is $CO_2$. Is that correct?

Mr. MICHAELS. There are instances in that record where in fact the temperature changes precede the changes in carbon dioxide.

Mr. BARTON. So what we have is a theory that $CO_2$ is driving temperature but that is all it is. It is a theory. It is not a scientific fact, is it?

Mr. MICHAELS. Well, no. This argument gets very, very complicated. Carbon dioxide in laboratory experiments is demonstrated to absorb in the infrared, and everything else being equal, you will get a warming from $CO_2$. That is really not the point that I am trying to make. The point is that the warming has been tending to run underneath what is projected by our midrange models and so therefore there is a reasonable argument that the sensitivity that is within the models for very complicated reasons has been overestimated.

Mr. BARTON. That little beep beep means our time has expired.

Mr. MICHAELS. I am sorry.

Mr. BARTON. We appreciate the discretion of the chairman and we look forward to him showing more discretion in future hearings.

Mr. MARKEY. And it will be forthcoming. The gentleman's time has expired. The chair recognizes the gentleman from Washington State, Mr. Inslee.

Mr. INSLEE. Dr. Michaels, I am stunned that you have come here and talked about things that just don't seem to make any scientific sense to me. I have listened to your testimony with care, and what you did is, you compared observational data in the past to models in the future and you said that the rate of change in the models of the future are different than the observational data in the past, that there must be something wrong with the model. Now, that makes no sense whatsoever on a scientific basis. If you want to compare models to observational data, you have to do it in the same time period, and in fact, the observational data with the modeling data in the past is quite consistent. You showed a difference

between observational data in the past and modeling projections in the future, and there is some difference because it shows an accelerated rate of warming, which is consistent with what is going on in the real world. Now, how can you possibly come here and think you are going to blow this one right by us and nobody is going to figure this out? Do you take us for real chumps up here?

Mr. MICHAELS. I really would prefer that we do not get personal. In fact, there is substantial overlap between the period that I looked at. Half of the period that I looked at overlaps the models. Number two, and we could go to my graphics. I don't know how hard they would be to come up with. Can we go to——

Mr. INSLEE. Sure. Let us do that. Let me ask the staff to put up the global mean surface temperature chart, source IPCC/AR-4. Can you put that up, please? Because I think what we will see is if you were forthright with this committee, you would say that the modeling data is quite consistent with the observational data in the past.

Mr. SHIMKUS. Mr. Chairman, would you yield for a second? I would ask my colleague from Washington State not to disparage and call the panelist a liar. When you propose the fact that he is not forthright, you are making the premise that he is actually providing testimony that is not true. He is a noted citizen, respected policy observer on the U.N. climate, and I think it is just egregious that we attack the only Republican panelist we have on this committee when you have five on your side.

Mr. MARKEY. Let me just note that the gentleman from Washington State did not use the word "liar."

Mr. SHIMKUS. He said he was not forthright. Mr. Chairman, we can quibble about words but we know what that means.

Mr. MARKEY. Well, I appreciate that, but I think, as we know——

Mr. MICHAELS. I think I can defuse this with a very simple answer.

Mr. MARKEY. If I may, Dr. Michaels, there is a difference in terms of which term is used in terms of the response someone is trying to elicit from a witness, and we are going to put the time back on the clock for the gentleman from Washington State, and I don't think that the gentleman from Washington State was doing anything other than trying to engage in—by using the word "forthright", trying to use terminology that would have a scientific discussion. If he had used the word "liar" or if any member uses the word "liar" here, I am going to rule them out of order in this hearing or any other hearing. If he engages in the use of language which is commonly considered to be abusive, I will do that. I don't think using the word "forthright" in the way in which he did it in this scientific discussion really was intended to be a personal insult. If anything, the gentleman from Washington was using the word "chump" to refer to himself in this discussion and I felt that that was also an inappropriate word.

Mr. INSLEE. That may have been over the line. I will apologize for myself——

Mr. MARKEY. In my opinion, that was——

Mr. INSLEE [continuing]. My self-descriptive chumpdom.

Mr. MARKEY [continuing]. A self description.

Mr. INSLEE. And I want to say for the record——

Mr. MARKEY. I will put the time back on the clock up to approximately 3 minutes.

Mr. INSLEE. Thank you, and I want to make clear that Mr. Shimkus is always forthright, and I appreciate his observations. But I do want to point out that I think a forthright assessment of the scientific principles is that one does not compare apples to oranges and criticize a model that has essentially been accurate with observational data, and if you look at the chart that is on the screen now, it will compare the modeling data to observational data prior to the year 2004, and I think you will see there is a very high degree of correspondence between the two showing that the modeling data compared to observational data in the past are very, very close. Now, what we have seen with the modeling data, a forthright statement is that the model suggests an accelerating rate of global warming and in fact that is what we have experienced and that is why everyone with their eyes open are now seeing very significant changes in our climatic system. I will ask Professor Schrag to comment on that if that is a fair assessment of the evidence.

Mr. SCHRAG. I think that is a fair assessment, and I think it is correct that the models are predicting an accelerated response over the next several decades. Part of the reason is what I said earlier, the aerosol effect that has been essentially dampening the effect of $CO_2$ is short-lived and over time we will see the $CO_2$ continue to accumulate and the impact of $CO_2$ grow and grow relative to the aerosol forces.

Mr. INSLEE. And I may note the acceptance of this forthright scientific data is becoming so widespread that this is a debate we should not be having. Today I just got a message on my BlackBerry that Exxon Oil was at a meeting yesterday or this morning talking about the need to respond to global warming. This just isn't a debate anymore, and it is unfortunate that our committee is sort of fighting the Civil War again, and we have to stop fighting the Civil War and try to find a bipartisan consensus on how to move forward, and I really look forward to the day when the witnesses who are before us from the Republican side will talk about how we design a cap-and-trade system that will minimize any dislocation. I just look forward to that day. I hope it is coming shortly because I think the forthright conclusion we can draw on a bipartisan basis is that we know what is going on, it is not good, and I look forward to the day we can jointly figure out a way to solve that.

Thank you. I yield back.

Mr. MICHAELS. Mr. Chairman, can I respond?

Mr. INSLEE. You have 15 seconds if you like. Go ahead.

Mr. MICHAELS. OK. These are the A1B scenarios. I hope you have good eyes. You can see that the rates are in fact not accelerating over the course of 100 years, in fact, they are constant, and that the rates that are being observed which are also constant are at the low end of the projection ranges made by the A1B scenarios. Those are constant. If you have good eyes back there, you can see that. Thank you very much.

Mr. INSLEE. Thank you to all witnesses.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Kentucky, Mr. Whitfield.

Mr. WHITFIELD. Thank you, Mr. Chairman. I think the frustrating thing about this debate is, I read an article the other day where someone said that in all my years of doing science, I have never seen this sort of gag order on people trying to speak their views, whether they disagree or agree with the projections of the impact of global warming, and that stems from the fact that Dr. Michaels, because of actions taken by Governor Tim Kaine of Virginia, Dr. Michaels was state climatologist and actually lost his job there and at the University of Virginia because he continued to speak out on global warming, which was different than the position of the governor. In addition to that, an official in Oregon lost his job because his views were different than those of the governor of Oregon. He continues to speak out on global warming. In Delaware, Governor Ruth Ann Minner got upset because one of the climatologists there participated in an amicus curiae brief before the Supreme Court in which they were questioning some of the scientific evidence on global warming. In Washington State, Mark Albright lost his job for the same reason. And I think it is disturbing that on an issue this important that can have the impact in the future that this has, that we get into these kinds of situations. I think the important aspect of this is that everybody give their views and then let us make decisions and try to solve the problem.

I noticed that Professor Schrag made the comment that generally they are very conservative in their arguments about global warming and the impact of global warming and yet when I read Dr. Ackerman's testimony on footnote 4, which he talks about on page 5, he said since the future will only happen once and we want to know how bad the risk of future damages could be, we are going to use the worst limit of what IPCC calls the likely range of outcomes, and that is fine, but as politicians when we go out to civic clubs and everywhere else and we make speeches, we try to find evidence that will back us up, and when you get people who are really totally convinced that we need to take drastic action to prevent the impact of global warming in the future, we are going to take the studies, the worst-case scenario being according to Dr. Ackerman that by 2100, U.S. temperatures are going to rise 12 to 13 degrees Fahrenheit. In Alaska they are going to rise by 18 degrees Fahrenheit. Sea levels are going to increase by 45 inches and hurricane intensity will create damages estimated to be $397 billion by 2100.

Now, I might also say that Chris Lancey, who was contributing to the IPCC in the area of hurricanes, resigned from the IPCC because he said that the leading author had a press conference and emphatically stated that increased hurricane intensity was due to global warming, and Lancey resigned from that. The reason I know about that because we had a lengthy oversight hearing about that a number of years ago. Now, Dr. Ackerman, I know you want to make a comment, Dr. Michaels wants to make a comment, so Dr. Ackerman, you go ahead.

Mr. ACKERMAN. OK. We did look at not the absolutely worst case but the 83rd percentile of the range that was suggested, the worst

of the IPCC likely. It means the 83rd percentile. The future is going to happen once and a cost-benefit calculation based on the average or most likely gives you a 50 percent chance of not being bad enough. People don't think that way in ordinary life. Insurance, which never passes a cost-benefit test, is what people do when they are facing a severe risk which they can't afford. That is absolutely what we are facing here. The science, you know, what it looks like at the 83rd percentile of risk for this century looks pretty bad. Now, in terms of the hurricane debate, I know there has been a lot of debate about the details of that. Roger Pielke Jr. is one of the critics of the position that we took on hurricanes, read over my reports. I had a long correspondence with him. He persuaded me that I had a small numerical error that made it 6 percent too high. He was very happy to hear that I corrected it. There is another footnote in my testimony that tells you that I am using the numbers based on my correspondence with him.

Mr. WHITFIELD. And thank you very much for that. My time has expired but I would like Dr. Michaels to be able to make his comment as well.

Mr. MICHAELS. Well, there are several places that I would like to comment and obviously do not have time for it. I will say in the Stern Report, which has been oft quoted here, that the worst-case climate scenarios are assumed and the discount rates are thought to be economically very unrealistic. With regard to the employment problems that certain people have had, I just think that is very sad. We thrive on intellectual diversity. People are not promoted from assistant to full professor at major universities for doing nothing, and for the political process to have interfered there is a very, very, very black and sad thing.

Mr. MARKEY. The gentleman's time has expired. The chair recognizes the gentleman from Texas, Mr. Green.

Mr. GREEN. Thank you, Mr. Chairman. Before I get into some of the questions, I would like to ask Mr. Woolsey, you made a statement a few minutes ago that you get the same credit for not burning coal to create electricity as you do if you don't burn natural gas, and that is not what I understood. I thought that coal plants emit much more carbon than, say, a natural gas plant.

Mr. WOOLSEY. Coal plants do produce a greater amount of carbon per BTU than natural gas does. What I was saying was that the instrumentality of the renewable portfolio standard doesn't really discriminate between gas and coal. It just wants an increase in renewables. There was a very good op-ed in the Wall Street Journal about this a couple of weeks ago and that I thought a feed-in tariff was a superior mechanism to a renewable portfolio standard for the purpose of emphasizing renewables in a more effective way.

Mr. GREEN. Thank you for that clarification because if we are looking at controlling carbon, a renewable standard may be one of the avenues, but we also need to make sure that renewable standard is something that you are ultimately going after with the carbon capture or the carbon sequestration.

Dr. Ackerman, in order to evaluate the cost of inaction on climate change, you compare the economic consequences of two possible climate scenarios in a business-as-usual case or unchecked growth in greenhouse gas emissions with rapid stabilization case, whereby

the United States reduces its emissions by 80 percent accompanied by a 50 percent reduction in total world emissions. Under your rapid stabilization case, what happens if only the United States acts to reduce its emissions while major emitters such as China or India do not follow suit? Will the cost of inaction become smaller or greater?

Mr. ACKERMAN. There is really no hope of solving this problem if we don't have a global agreement on it. No country represents more than 20 percent of the total. The United States and China are both at about that point so——

Mr. GREEN. Thank you. Since we only have 5 minutes and I have a whole lot of questions, I thank you for that. My next follow-up is, so in your opinion, it is crucial that reductions in greenhouse gas emissions are linked to a global action to reduce carbon emissions?

Mr. ACKERMAN. Absolutely. It has to be done globally.

Mr. GREEN. Could we ever achieve a rapid stabilization case without strong mandatory reductions by other major emitters?

Mr. ACKERMAN. No. Everybody has to agree to reduce.

Mr. GREEN. Your analysis found that under the business-as-usual case, combined increased costs for electricity added up to $141 billion per year in 2001 or .14 percent of projected U.S. output. Last year there was an EPA analysis of climate change legislation, Senate bill 1766, by Bingaman and Specter and the Senate found that electricity prices were projected to increase 40 percent in 2030 and an additional 25 percent in 2050. How do these increased costs of climate change addressing climate change in the EPA analysis compare with your estimates under a business-as-usual case for electricity rates?

Mr. ACKERMAN. I haven't looked at that EPA study. I know that our subcontractors, who analyze the electric power system were actually quite conservative in the costs that they were able to look at, mostly looking at increased air conditioning load. There are a number of other effects on the power system which they were not able to quantify so I would not be surprised if someone else came up with a higher number.

Mr. GREEN. I appreciate it coming from a part of the country that we need LIHEAP from May to September for our poor folks. I appreciate that.

Mr. Woolsey, you made several observations in your work on malevolent and malignant threats regarding climate change impacts on our energy infrastructure. Can you further elaborate on your point that our energy systems are vulnerable to climate change?

Mr. WOOLSEY. Well, they contribute to climate change insofar particularly as they use coal and oil but they are also vulnerable. For example, Hurricane Katrina barely missed the Colonial Pipeline, which is a major pipeline from the Gulf up to the East Coast. Most of us around here would have done a good deal more bicycling and walking had Katrina been just a mile or two different from where it was, and the electricity grid in Cleveland suffered an outage in August of 2003 when a tree branch touched a power line in the middle of a storm, and within 9 seconds some 50 million consumers were offline in the United States and eastern Canada. Now, probably 2 decades ago that would have been an outage in part of

Cleveland, but because our electricity grid is so stressed and is so overloaded with the demands of running a deregulated system and everybody being able to shop all over the country for every little bit of electricity and so on, it has produced an extraordinarily vulnerable system, vulnerable to natural interference, such as a tree branch touching a power line, and unfortunately, terrorists are a lot smarter than tree branches.

Mr. GREEN. And I appreciate that, and hopefully this stimulus reinvestment bill that has money in there for transmission expansion and also other things will help that, because that is one of the issues. We need to have alternatives to having just one line.

I have one more question if I could——

Mr. MARKEY. Very quick.

Mr. GREEN. Dr. Ebi, can you explain how increasing temperatures could facilitate the development of ground-level ozone and how this could impact public health within pollution-prone areas? Specifically, do you suggest that the United States coordinate the public health responses to climate change across the level of Federal Government?

Ms. EBI. The rate at which ground-level ozone is formed, and it is formed on clear, cloudless days, the rate is temperature dependent. All else being equal, if the temperature goes up there will be more ground-level ozone.

Mr. GREEN. And how do you suggest we coordinate between our public health responses? Because, again, coming from the Houston area, we have an ozone problem, and is it coordination of the federal agencies in response to that is what we should do?

Ms. EBI. There needs to be coordination not only with the Federal Government but across borders because there is also hemispheric transport of ozone.

Mr. GREEN. Thank you.

Mr. MARKEY. The gentleman's time has expired. We will recognize the gentleman from Illinois for 6½ minutes.

Mr. SHIMKUS. Thank you, Mr. Chairman. I did an opening statement so——

Mr. MARKEY. I am going to balance you out with Mr. Green.

Mr. SHIMKUS. Thank you, Mr. Chairman. I would like, Mr. Chairman, if we could submit James Connaughton's report from December 2007 on the Energy and Climate Policy. In here there is a couple of noted aspects, $37 billion in climate change. Before the stimulus bill, that would have been real money in Washington. Now $37 billion is chump change, but I would say that is doing something. I would also want to highlight an issue in here about the important transitions of emitting countries. It does address what are some of the answers. We are really flatline growth from 1990 projected to 2095. It is the developing countries. I can guarantee you the developing countries are not going to go into a worldwide climate policy. We met with the Chinese a few years ago, asked them a couple times. Their basic response was, you had your chance to get to the middle class, now it is ours.

The only thing we have is fear left, Mr. Chairman. It is fear on the stimulus, $900 billion. It is fear for immediate action on climate change. When in the world do we stop attacking a messenger of a divergent scientific opinion? And shame on us for doing so. If

we were to apply the Fairness Doctrine that we are going to try to ram down America on telecommunications policy, the Fairness Doctrine would say three panelists for a view on climate change that is supportive of what Dr. Michaels is speaking of and three in opposition, so I would hope that as we talk about Fairness Doctrine, that would be brought to the committee.

Let me ask, how would each of you respond—of course, I have very limited time—to this statement: We will harness the sun and the winds and the soil to fuel our cars and run our factories. True or false, Dr. Michaels?

Mr. MICHAELS. I can't give you an answer.

Mr. SHIMKUS. Dr. Ackerman?

Mr. ACKERMAN. I would need more information.

Mr. SHIMKUS. Dr. Ebi?

Ms. EBI. I agree, there would need to be additional information before I could comment.

Mr. SHIMKUS. OK. Here is a statement: We will harness the sun and the winds and the soil for fuel to fuel our cars and run our factories. Mr. Woolsey?

Mr. WOOLSEY. Today I drive a plug-in hybrid and I have photovoltaic cells on my roof and batteries in my basement, and I drive 40 to 50 miles a day on sunlight.

Mr. SHIMKUS. I mean yes or no.

Mr. WOOLSEY. Yes, it can be done.

Mr. SHIMKUS. And your electricity comes from what commodity product?

Mr. WOOLSEY. It comes from Baltimore Gas and Electric, which is whatever they use. Some of it is coal, some of it is other. But——

Mr. SHIMKUS. But that is not wind and that is not solar.

Mr. WOOLSEY. They are moving into——

Mr. SHIMKUS. And that is not renewable as by the definition of our——

Mr. WOOLSEY. Solar is part of it.

Mr. SHIMKUS. Again, I am just saying this statement.

OK. Let us go to General Sullivan.

General SULLIVAN. I have no idea.

Mr. SHIMKUS. OK. Yes. Thank you. An honest answer. I will tell you, you are not going to operate a United States steel mill on wind, on solar, on renewables.

Mr. WOOLSEY. It will take a lot longer.

Mr. SHIMKUS. Well, I will say you will never run a United States steel mill on wind, on solar, on renewables.

Mr. WOOLSEY. I disagree.

Mr. SHIMKUS. And that is what this process is all about.

Professor Schrag?

Mr. SCHRAG. I think what is missing from this question is the time scale. In the next decade it is going to be very hard to switch off of fossil fuels. It is more than 80 percent of our energy. Long-term scales, we are going to have to because we are going to run out and that is just the way it is. It is going to get very expensive. And, you know, today in Iceland, for example, Alcoa is building aluminum smelting plants that are run on geothermal so it is possible, it is just expensive in other parts of the world and in the United States today, but at some point fossil fuels are going to get even

more expensive, and the security issues associated with that are serious.

Mr. SHIMKUS. Well, in this part of our debate on climate change, because those of us who are for all-of-the-above strategy, if you want to talk national security and having reliable power, the nuclear power has to be part of this debate. The environmental left has yet to come to the table to believe that growth in the nuclear power movement in this country. They continue to block the ability to store high-level nuclear waste at Yucca Mountain. They will allow the continued storing of this on site to a point where the reservoirs will be full, and these sites will have to be decommissioned. We are actually paying federal tax dollars to these companies to store the waste that we have agreed to hold.

I would like to ask Dr. Michaels, I think a lot of us are concerned especially with the comments made today and your lone voice and this issue of fear. I mean, you hear the world is going to end and we have to do something now. Tell me why you believe there is this rush to act.

Mr. MICHAELS. That is a very complicated question. It is obviously political. Obviously a lot of voices are not being heard. And my fear, my fear is that that is going to have a very counterproductive effect and I really want the committee to consider this. If you take capital out of the system with expensive taxes and cap-and-trade programs, that capital would normally be used by individuals in their 401(k)s for investment and those investments are often made in companies that produce things efficiently or produce efficient things compared to their competitors. They are advantaged in the competitive marketplace. So you can have a very counterproductive effect by putting in regressive energy taxes or other programs like that. You take capital out of the system that would normally be used for investment in companies that produce things efficiently. This is very, very obvious that people are doing this. I ask you to take a look at the share prices of various producers of automobiles and take a look at the share prices of those——

Mr. SHIMKUS. And let me be real quick, Professor Schrag, just your quick answer on coal-to-liquid technologies. Support it? I mean, in your testimony you talked about being able to pull off the carbon stream.

Mr. SCHRAG. Coal to liquids, if done improperly the way the South Africans do, is one of the dirtiest technologies in the world. If it is done properly with biomass blending and carbon sequestration, it can be among the cleanest technologies in the world.

Mr. SHIMKUS. Mr. Chairman, did you hear that testimony? It is your witness. Did you hear his answer?

Mr. MARKEY. I am sorry.

Mr. SHIMKUS. I am teasing.

Mr. MARKEY. No, can you repeat the answer?

Mr. SHIMKUS. I am just teasing, Mr. Chairman.

Mr. MARKEY. I would really like to hear the answer again, please.

Mr. SCHRAG. The answer was that the same technology that makes incredibly dirty fuel in South Africa, twice the emissions of regular oil, if done properly with the right regulations, with blending biomass with the coal, and what we are talking about could be

waste biomass or wood chips, and capturing the carbon from the process can actually produce very efficient, clean fuel, but it has to be done right, not in a dirty fashion.

Mr. MARKEY. I will just say to the gentleman, in the stimulus bill, the House put in $2.5 billion for carbon capture and sequestration, trying to find ways of using technologies that can sequester the carbon. The Senate put in about $4 billion. The debate is not over whether or not we should be doing something in this area, the debate is over how many billions of dollars we should be spending in this area. So that is really not what this debate is about.

Mr. SHIMKUS. Yes, and we haven't seen the commerce report, Mr. Chairman, but I think that has now been cut to $1 billion from what I have heard. But I do need to just give credit to the quote I used on "We will harness the sun and the winds and the soil to fuel our cars and run our factories," President Barack Obama, my State. We are very excited but this is part of the research you have to do to find out exactly what people are saying because this is impossible in the near term.

Mr. MARKEY. I thank the gentleman and I thank all of the witnesses as well. This has been a very, very helpful stage-setting hearing for us. We discussed the economics, the national security, and the health implications of climate change, and I think what we heard here today is that there is a real urgency for our country to become the leader, and that is the intention of this subcommittee and full committee. We intend on acting this year in a way that deals with the urgency of the problem, and there is good news. The good news includes the fact that 42 percent of all new electrical generating capacity installed in 2008 was wind power, 50 percent was natural gas, so that is not a bad formula for dealing with climate change, and I think that is going to accelerate in the years ahead, even as we do the research and deal with carbon capture and sequestration to try to accommodate coal in the years ahead. So that is a huge number, 42 percent of all new electrical generation capacity. It can be expected to go to 50 and 60 percent in the years ahead as a national renewable electricity standard is adopted.

So I am very optimistic, and this panel has helped to pinpoint the problem, but talk about some of the solutions as well, and we thank you for that, and with the thanks of the committee, this hearing is adjourned. Thank you.

[Whereupon, at 12:35 p.m., the subcommittee was adjourned.]

[Material submitted for inclusion in the record follows:]

## PREPARED STATEMENT OF HON. GENE GREEN

Mr. Chairman, thank you for holding our subcommittee's first hearing this morning to evaluate the impacts of climate change on the United States.

The International Panel on Climate Change (IPCC) reports clear scientific consensus that human activities have increased emissions of carbon and other greenhouse gases which contribute to global warming.

The questions many continue to grapple with, however, are to what extent will future warming occur and at what costs to our society?

Several experts in academia, government, and the private sector believe climate change could have ramifications not only on global temperatures, but on America's overall economy, public health, and national security.

For example, a representative from the Center for Disease Control and Prevention testified last Congress that climate change is likely to have a "significant impact on

health" caused by extreme heat and weather, air pollution, and water-borne infectious diseases.

For urban areas like Houston, higher temperatures have been shown to facilitate the development of ground-level ozone which can lead to respiratory illnesses, asthma, and lung damage.

I am also concerned with the anticipated impacts of climate change on severe weather systems, particularly in the Gulf of Mexico.

The Gulf Coast has already recently been battered by Hurricanes Ike and Katrina which have proven the vulnerability of these areas to loss of life and property.

Perhaps the timeliest factor is the economic cost associated with addressing, or not addressing, climate change.

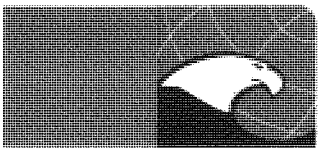
America is facing the worst financial crisis since the Great Depression and many family budgets are already stretched past their breaking point.

Last year, government analysis by both the EPA and EIA found that climate change legislation would increase the cost of gasoline and electricity for American consumers and businesses.

I have concerns with the timing of this extra burden on hard-working Americans and believe any efforts to address climate change must protect both our environment and our economy.

I look forward to the testimony of our witnesses today, and I yield back the balance of my time.

Thank you Mr. Chairman.



**NATIONAL SECURITY AND THE THREAT OF CLIMATE CHANGE**

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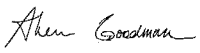

**Sherri Goodman**
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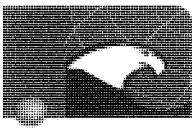

**NATIONAL SECURITY AND THE THREAT OF CLIMATE CHANGE**

*To the reader,*



During our decades of experience in the U.S. military, we have addressed many national security challenges, from containment and deterrence of the Soviet nuclear threat during the Cold War to terrorism and extremism in recent years.

Global climate change presents a new and very different type of national security challenge.

Over many months and meetings, we met with some of the world's leading climate scientists, business leaders, and others studying climate change. We viewed their work through the lens of our military experience as warfighters, planners, and leaders. Our discussions have been lively, informative, and very sobering.

Carbon dioxide levels in the atmosphere are greater now than at any time in the past 650,000 years, and average global temperature has continued a steady rise. This rise presents the prospect of significant climate change, and while uncertainty exists and debate continues regarding the science and future extent of projected climate changes, the trends are clear.

The nature and pace of climate changes being observed today and the consequences projected by the consensus scientific opinion are grave and pose equally grave implications for our national security. Moving beyond the arguments of cause and effect, it is important that the U.S. military begin planning to address these potentially devastating effects. The consequences of climate change can affect the organization, training, equipping, and planning of the military services. The U.S. military has a clear obligation to determine the potential impacts of climate change on its ability to execute its missions in support of national security objectives.

Climate change can act as a threat multiplier for instability in some of the most volatile regions of the world, and it presents significant national security challenges for the United States. Accordingly, it is appropriate to start now to help mitigate the severity of some of these emergent challenges. The decision to act should be made soon in order to plan prudently for the nation's security. The increasing risks from climate change should be addressed now because they will almost certainly get worse if we delay.

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# ACKNOWLEDGMENTS

We are thankful to several people for their support of this effort. Rear Adm. Richard Pittenger, USN (Ret.) of the Woods Hole Oceanographic Institution, and Dr. Fiona Horsfall of the National Oceanic and Atmospheric Administration provided many valuable insights into climate science and reviewed our draft report. Dr. Robert Frosch, former assistant secretary of the Navy for research and development and former NASA administrator, currently at Harvard University, also reviewed our draft report and provided suggestions for improvement regarding the science of climate change. Dr. Kent Butts of the Army War College, Dr. Geoffrey D. Dabelko of the Woodrow Wilson International Center for Scholars, and Franklin D. Kramer, former assistant secretary of defense, reviewed our report and provided valuable comments on sources of conflict and security issues related to climate change.

We thank the following persons for briefing the Military Advisory Board: Dr. James Hansen, lead climate scientist and director, NASA Goddard Institute for Space Studies; Dr. Anthony Janetos of the H. John Heinz III Center for Science, Economics and the Environment; Dr. Richard Moss, senior director, Climate and Energy, United Nations Foundation, formerly director of the U.S. Global Change Research Program Office; Mr. Justin Mundy, senior advisor to the Special Representative on Climate Change, UK Foreign and Commonwealth Office; Maj. Gen. Richard Engel, USAF (Ret.), deputy national intelligence officer for science and technology, National Intelligence Council; Mr. Randy Overbey, former president, Alcoa Primary Metals Development; Mr. Kenneth Colburn, of the Center for Climate Strategies; and Dr. Robert Socolow of Princeton University.

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# EXECUTIVE SUMMARY

The purpose of this study is to examine the national security consequences of climate change. A dozen of the nation's most respected retired admirals and generals have served as a Military Advisory Board to study how climate change could affect our nation's security over the next 30 to 40 years—the time frame for developing new military capabilities.

The specific questions addressed in this report are:

1. What conditions are climate changes likely to produce around the world that would represent security risks to the United States?
2. What are the ways in which these conditions may affect America's national security interests?
3. What actions should the nation take to address the national security consequences of climate change?

The Military Advisory Board hopes these findings will contribute to the call President Bush made in his 2007 State of the Union address to "...help us to confront the serious challenge of global climate change" by contributing a new voice and perspective to the issue.

## FINDINGS

**Projected climate change poses a serious threat to America's national security.**
The predicted effects of climate change over the coming decades include extreme weather events, drought, flooding, sea level rise, retreating glaciers, habitat shifts, and the increased spread of life-threatening diseases. These conditions have the potential to disrupt our way of life and to force changes in the way we keep ourselves safe and secure.

In the national and international security environment, climate change threatens to add new hostile and stressing factors. On the simplest level, it has the potential to create sustained natural and humanitarian disasters on a scale far beyond those we see today. The consequences will likely foster political instability where societal demands exceed the capacity of governments to cope.

Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world. Projected climate change will seriously exacerbate already marginal living standards in many Asian, African, and Middle Eastern nations, causing widespread political instability and the likelihood of failed states.

Unlike most conventional security threats that involve a single entity acting in specific ways and points in time, climate change has the potential to result in multiple chronic conditic occurring globally within the same time frame. Economic and environmental conditions in already fragile areas will further erode as food production declines, diseases increase, clean water becomes increasingly scarce, and large populations move in search of resources. Weakened and failing governments, with an already thin margin for survival, foster the conditions for internal conflicts, extremism, and movement toward increased authoritarianism and radical ideologies.

The U.S. may be drawn more frequently into these situations, either alone or with allies, to help provide stability before conditions worsen and are exploited by extremists. The U.S. may also be called upon to undertake stability and reconstruction efforts once a conflict has begun, to avert further disaster and reconstitute a stable environment.

Projected climate change will add to tensions even in stable regions of the world. The U.S. and Europe may experience mounting pressure to accept large numbers of immigrant and refugee populations as drought increases and food production declines in Latin America and Africa. Extreme weather events and natural disasters, as the U.S. experienced with Hurricane Katrina, may lead to increased missions for a number of U.S. agencies, including state and local governments, the Department of Homeland Security, and our already stretched military, including our Guard and Reserve forces.

Climate change, national security, and energy dependence are a related set of global challenges. As President Bush noted in his 2007 State of the Union speech, dependence on foreign oil leaves us more vulnerable to hostile regimes and terrorists, and clean domestic energy alternatives help us confront the serious challenge of global climate change. Because the issues are linked, solutions to one affect the other. Technologies that improve energy efficiency also reduce carbon intensity and carbon emissions.

## RECOMMENDATIONS OF THE MILITARY ADVISORY BOARD:

**1. The national security consequences of climate change should be fully integrated into national security and national defense strategies.**

As military leaders, we know we cannot wait for certainty. Failing to act because a warning isn't precise enough is unacceptable. The intelligence community should incorporate climate consequences into its National Intelligence Estimate. The National Security Strategy should directly address the threat of climate change to our national security interests. The National Security Strategy and National Defense Strategy should include appropriate guidance to military planners to assess risks to current and future missions caused by projected climate change. The next Quadrennial Defense Review should examine the capabilities of the U.S. military to respond to the consequences of climate change, in particular, preparedness for natural disasters from extreme weather events, pandemic disease events, and other related missions.

**2. The U.S. should commit to a stronger national and international role to help stabilize climate change at levels that will avoid significant disruption to global security and stability.**

Managing the security impacts of climate change requires two approaches: mitigating the effects we can control and adapting to those we cannot. The U.S. should become a more constructive partner with the international community to help build and execute a plan to prevent destabilizing effects from climate change, including setting targets for long term reductions in greenhouse gas emissions.

**3. The U.S. should commit to global partnerships that help less developed nations build the capacity and resiliency to better manage climate impacts.**

As President Bush noted in his State of the Union speech, "Our work in the world is also based on a timeless truth: To whom much is given, much is required." Climate forecasts indicate countries least able to adapt to the consequences of climate change are those that will be the most affected. The U.S. government should use its many instruments of national influence, including its regional commanders, to assist nations at risk build the capacity and resiliency to better cope with the effects of climate change. Doing so now can help avert humanitarian disasters later.

4. The Department of Defense should enhance its operational capability by accelerating the adoption of improved business processes and innovative technologies that result in improved U.S. combat power through energy efficiency.

Numerous Department of Defense studies have found that combat forces would be more capable and less vulnerable by significantly reducing their fuel demand. Unfortunately, many of their recommendations have yet to be implemented. Doing so would have the added benefit of reducing greenhouse gas emissions.

5. The Department of Defense should conduct an assessment of the impact on U.S. military installations worldwide of rising sea levels, extreme weather events, and other projected climate change impacts over the next 30 to 40 years.

Many critical defense installations are located on the coast, and several strategically important ones are on low-lying Pacific islands. Sea level rise and storm surges will threaten these facilities. Planning and action can make these installations more resilient. Lack of planning can compromise them or cause them to be inundated, compromising military readiness and capability.

# ABOUT THE REPORT

To better inform U.S. policymakers and the public about the threats to national security from global climate change, the CNA Corporation, a nonprofit national security analysis organization, convened a panel of retired senior military officers and national security experts and conducted an assessment of the national security implications of global climate change. In this context, we define national security to refer to the influence of climate change on geo-strategic balances and world events that could likely involve U.S. military forces or otherwise affect U.S. strategic interests anywhere in the world.

The Military Advisory Board consisted of retired flag and general officers from all four services, including service chiefs and some who served as regional combatant commanders (a regional combatant commander is a four-star officer who commands all U.S. forces in a given region of the world). The Military Advisory Board and the study team received briefings from the U.S. intelligence community, climate scientists, and business and state leaders. They also traveled to the United Kingdom to meet with high-level government and business leaders to learn what actions the United Kingdom is taking to address the threat of climate change. Members of the Military Advisory Board also presented their own views, based on experience, of the security effects of climate change on various regions of the world.

This report documents the results of that effort. We start with a discussion of the geo-strategic implications of climate change in the general sense—that is, how climate change can foster instability and affect international security. We then apply this background to address specific regional security challenges in Africa, Asia, the Middle East, Europe, and the Americas. That is followed by a discussion of the challenges from climate change that can have a direct impact on military systems and operations. We conclude with a set of findings and recommendations related to mitigation, adaptation, and preparation—specific actions the U.S. government should take in response to the challenges presented by climate change. Appendices provide background on members of the Military Advisory Board, and very briefly summarize the science of climate change and ways in which the earth's environment may potentially change.

## CLIMATE CHANGE AND THE SCOPE OF THIS STUDY

Although there is a great deal of agreement among the world's climate scientists regarding the overall picture of a changing climate, there is also some disagreement about the extent of future changes.

Regardless of this continuing discussion, the board's view is quite clear: The potential consequences of climate change are so significant that the prudent course of action is to begin now to assess how these changes may potentially affect our national security, and what courses of action, if any, our nation should take.

This approach shows how a military leader's perspective often differs from the perspectives of scientists, policymakers, or the media. Military leaders see a range of estimates and tend not to see it as a stark disagreement, but as evidence of varying degrees of risk. They don't see the range of possibilities as justification for inaction. Risk is at the heart of their job: They

## GENERAL GORDON R. SULLIVAN, USA (Ret.)

*Chairman, Military Advisory Board | Former Chief of Staff, U.S. Army*

### ON RISK

Former U.S. Army Chief of Staff Gordon Sullivan enjoys a good debate. But he also knows there are times when debate must stop and action must begin. With respect to climate change, he says that time has arrived.

"We seem to be standing by and, frankly, asking for perfectness in science," Gen. Sullivan said. "People are saying they want to be convinced, perfectly. They want to know the climate science projections with 100 percent certainty. Well, we know a great deal, and even with that, there is still uncertainty. But the trend line is very clear."

"We never have 100 percent certainty," he said. "We never have it. If you wait until you have 100 percent certainty, something bad is going to happen on the battlefield. That's something we know. You have to act with incomplete information. You have to act based on the trend line. You have to act on your intuition sometimes."

"We never have 100 percent certainty. We never have it. If you wait until you have 100 percent certainty, something bad is going to happen on the battlefield."

In discussing how military leaders manage risk, Gen. Sullivan noted that significant attention is often given to the low probability/high consequence events. These events rarely occur but can have devastating consequences if they do. American families are familiar with these calculations. Serious injury in an auto accident is, for most families, a low probability/high consequence event. It may be unlikely, but we do all we can to avoid it.

During the Cold War, much of America's defense efforts focused on preventing a Soviet missile attack—the very definition of a low probability/high consequence event. Our effort to avoid such an unlikely event was a central organizing principle for our diplomatic and military strategies.

When asked to compare the risks of climate change with those of the Cold War, Gen. Sullivan said, "The Cold War was a specter, but climate change is inevitable. If we keep on with business as usual, we will reach a point where some of the worst effects are inevitable."

"If we don't act, this looks more like a high probability/high consequence scenario," he added.

Gen. Sullivan shifted from risk assessment to risk management.

"In the Cold War, there was a concerted effort by all leadership—political and military, national and international—to avoid a potential conf[illegible]," he said. "I think it was well known in military circles that we had to do everything in our power to create an environment where the national command authority—the president and his senior advisers—were not forced to make choices regarding the use of nuclear weapons.

"The situation, for much of the Cold War, was stable," Gen. Sullivan continued. "And the challenge was to keep it stable, to stop the catastrophic event from happening. We spent billions on that strategy.

"Climate change is exactly the opposite. We have a catastrophic event that appears to be inevitable. And the challenge is to stabilize things—to stabilize carbon in the atmosphere. Back then, the challenge was to stop a particular action. Now, the challenge is to inspire a particular action. We have to act if we're to avoid the worst effects."

assess and manage the many risks to America's security. Climate change, from the Military Advisory Board's perspective, presents significant risks to America's national security. Before explaining some of those risks, we touch on an important scientific point.

A global average temperature increase of 1.3°F (plus or minus 0.3°F) occurred over the twentieth century. But the temperature change on its own is not what shapes this security assessment. Rather, it is the impact that temperature increases can have on natural systems, including:

- Habitats
- Precipitation patterns
- Extreme weather events
- Ice cover
- Sea level

Throughout this report, we do not attempt to tie our findings regarding security implications to any one particular projection of future temperature changes, precipitation changes, or sea level rise whether due to ocean expansion or ice sheet breakup. Rather, our goal is to articulate the possible security implications of climate change and to consider mitigating steps the nation could take as part of an overall national security plan.

# GEO-STRATEGIC IMPLICATIONS OF CLIMATE CHANGE

# GEO-STRATEGIC IMPLICATIONS OF CLIMATE CHANGE

One reason human civilizations have grown and flourished over the last five millennia is that the world's climate has been relatively stable. However, when climates change significantly or environmental conditions deteriorate to the point that necessary resources are not available, societies can become stressed, sometimes to the point of collapse [1].

For those concerned about national security, stability is a primary goal. Maintaining stability within and among nations is often a means of avoiding full-scale military conflicts. Conversely, instability in key areas can threaten our security. For these reasons, a great deal of our national security efforts in the post-World War II era have been focused on protecting stability where it exists and trying to instill it where it does not.

This brings us to the connection between climate change and national security.

As noted, climate change involves much more than temperature increases. It can bring with it many of the kinds of changes in natural systems that have introduced instability among nations throughout the centuries.

In this chapter, we consider some of the ways climate change can be expected to introduce the conditions for social destabilization. The sources of tension and conflict we discuss here are certainly not solely due to climate change; they have been discussed by the national security community for many years. However, climate change can exacerbate many of them [2]. For example:

- Some nations may have impaired access to food and water.
- Violent weather, and perhaps land loss due to rising sea levels and increased storm surges, can damage infrastructure and uproot large numbers of people.
- These changes, and others, may create large number of migrants . When people cross borders in search of resources, tensions can arise.

When climates change significantly or environmental conditions deteriorate to the point that necessary resources are not available, societies can become stressed, sometimes to the point of collapse.

- Many governments, even some that look stable today, may be unable to deal with these new stresses. When governments are ineffective, extremism can gain a foothold.
- While the developed world will be far better equipped to deal with the effects of climate change, some of the poorest regions may be affected most. This gap can potentially provide an avenue for extremist ideologies and create the conditions for terrorism.

## THE DESTABILIZING IMPACTS OF CLIMATE CHANGE

### REDUCED ACCESS TO FRESH WATER

Adequate supplies of fresh water for drinking, irrigation, and sanitation are the most basic prerequisite for human habitation. Changes in rainfall, snowfall, snowmelt, and glacial melt have significant effects on fresh water supplies, and climate change is likely to affect all of those things. In some areas of the Middle East, tensions over water already exist.

Mountain glaciers are an especially threatened source of fresh water [3]. A modest rise in temperature of about 2° to 4°F in mountainous

## VICE ADMIRAL RICHARD H. TRULY, USN (Ret.)

*Former NASA Administrator, Shuttle Astronaut and the first Commander of the Naval Space Command*

### ON DRAWING HIS OWN CONCLUSIONS

Retired Vice Adm. Richard H. Truly was a space shuttle commander and NASA administrator and is a member of the National Academy of Engineering. When he began service as director of the Department of Energy's National Renewable Energy Laboratory in 1997, he reminded his staff that he would be confronted with a new set of issues.

"I told them that I was unencumbered with experience or knowledge of the energy business, and that I would need their help," Adm. Truly said. "I had a pretty steep learning curve."

One of the first issues he was asked to consider was the extent to which fossil fuel emissions were affecting the climate.

"I wasn't convinced by a person or any interest group—it was the data that got me."

"I was a total agnostic," Truly said. "I had spent most of my life in the space and aeronautics world, and hadn't really wrestled with this. I was open-minded."

"Over the course of the next few years, I started really paying attention to the data. When I looked at what energy we had used over the past couple of centuries and what was in the atmosphere today, I knew there had to be a connection. I wasn't convinced by a person or any interest group—it was the data that got me. As I looked at it on my own, I couldn't come to any other conclusion. Once I got past that point, I was utterly convinced of this connection between the burning of fossil fuels and climate change. And I was convinced that if we didn't do something about this, we would be in deep trouble."

Adm. Truly noted an ironic twist about his path to this conclusion. "I was NASA administrator when Jim Hansen was first talking about these issues," he said, referring to NASA's top climate scientist. "But I was focused elsewhere then, and I should have listened more closely. I didn't become a convert until I saw the data on my own."

"The stresses that climate change will put on our national security will be different than any we've dealt with in the past. For one thing, unlike the challenges that we are used to dealing with, these will come upon us extremely slowly, but come they will, and they will be grinding and inexorable. But maybe more challenging is that they will affect every nation, and all simultaneously. This is why we need to study this issue now, so that we'll be prepared and not overwhelmed by the required scope of our response when the time comes."

When asked about his experience twenty-five years ago in space, and how it affects him today, Adm. Truly said, "It does change you, there's no doubt about it. I have images burned in my [redacted] that will never go away—images of the earth and its fragility. I was a test pilot. I was an aviator. I was not an environmentalist. But I do love the natural environment, and seeing the earth from space was the experience that I return to when I think about what we know now about the climate."

"One of the things that struck me on my first day in space is that there is no blue sky. It's something that every human lives with on Earth, but when you're in space, you don't see it. It looks like there's nothing between you and the surface of the earth. And out beyond that, it looks like midnight, with only deep black and stars."

"But when you look at the earth's horizon, you see an incredibly beautiful, but very, very thin line. You can see a tiny rainbow of color. That thin line is our atmosphere. And the real fragility of our atmosphere is that there's so little of it."

regions can dramatically alter the precipitation mix by increasing the share falling as rain while decreasing the share falling as snow. The result is more flooding during the rainy season, a shrinking snow/ice mass, and less snowmelt to feed rivers during the dry season [4]. Forty percent of the world's population derives at least half of its drinking water from the summer melt of mountain glaciers, but these glaciers are shrinking and some could disappear within decades. Several of Asia's major rivers—the Indus, Ganges, Mekong, Yangtze, and Yellow—originate in the Himalayas [4]. If the massive snow/ice sheet in the Himalayas—the third-largest ice sheet in the world, after those in Antarctic and Greenland—continues to melt, it will dramatically reduce the water supply of much of Asia.

Most countries in the Middle East and northern Africa are already considered water scarce, and the International Water Resource Management Institute projects that by 2025, Pakistan, South Africa, and large parts of India and China will also be water scarce [5]. To put this in perspective: the U.S. would have to suffer a decrease in water supply that produces an 80 percent decrease in per capita water consumption to reach the United Nations definition of "water scarce." These projections do not factor in climate change, which is expected to exacerbate water problems in many areas.

### IMPAIRED FOOD PRODUCTION

Access to vital resources, primarily food and water, can be an additional causative factor of conflicts, a number of which are playing out today in Africa. Probably the best known is the conflict in Darfur between herders and farmers. Long periods of drought resulted in the loss of both farmland and grazing land to the desert. The failure of their grazing lands compelled the nomads to migrate southward in search of water and herding ground, and that in turn led to conflict with the farming tribes occupying those lands. Coupled with population growth, tribal, ethnic, and religious differences, the competition for land turned violent. Probably more than any other recent conflict, Darfur provides

**In some areas of the Middle East, tensions over water already exist.**

a case study of how existing marginal situations can be exacerbated beyond the tipping point by climate-related factors. It also shows how lack of essential resources threatens not only individuals and their communities but also the region and the international community at large.

Worldwide food production will be affected by climate change in a variety of ways. Crop ecologists estimate that for every 1.8°F rise in temperature above historical norms, grain production will drop 10 percent [6].

Most of the world's growth in food demand is occurring on the Indian subcontinent and in sub-Saharan Africa, areas already facing food shortages [6]. Over the coming decades, these areas are expected to become hotter and drier [7].

### HEALTH CATASTROPHES

Climate change is likely to have major implications for human health. While some impacts, such as reduced deaths from cold temperatures in some areas, will be positive, the World Health Organization estimates that the overall impact will be negarive [8].

The major concern is significant spreading of the conditions for vector-borne diseases, such as dengue fever and malaria, and food-borne diseases, such as salmonellosis [8]. The decline in available fresh water in some regions will also have an impact, as good health and adequate supplies of clean water are inextricably linked.

A health emergency involving large numbers of casualties and deaths from disease can quickly expand into a major regional or global security

challenge that may require military support, ranging from distribution of vaccines to full-scale stability operations [9].

### LAND LOSS AND FLOODING: DISPLACEMENT OF MAJOR POPULATIONS

About two-thirds of the world's population lives near coastlines [10], where critically important facilities and infrastructure, such as transportation routes, industrial facilities, port facilities, and energy production and distribution facilities are located. A rise in sea level means potential loss of land and displacement of large numbers of people. Even in our own nation, Hurricane Katrina showed the social upheaval and tensions that can result from land loss and displaced populations. But while the impact of inundation from one-time occurrences such as Hurricane Katrina is temporary, even as it is devastating, inundation from climate change is likely to be permanent on the scale of human lifetimes. Rising sea levels will also make coastal areas more vulnerable to flooding and land loss through erosion.

Storm surges will also take a greater toll on coastal communities and infrastructure as sea levels rise. According ro a Pacific Institute study, a six-inch rise in the water level of San Francisco Bay would mean a fairly routine one-in-ten-year storm would wreak as much damage as a far more serious "hundred-year storm" would have caused before the sea level rise [11]. In the U.S., we may be able to cope with such a change, but poorer nations would be greatly challenged.

Most of the economically important major rivers and river deltas in the world—the Niger, the Mekong, the Yangtze, the Ganges, the Nile, the Rhine, and the Mississippi—are densely populated along their banks. As sea levels rise and storm surges increase, saline water can contaminate groundwater, inundate river deltas and valleys, and destroy croplands.

## SECURITY CONSEQUENCES OF THESE DESTABILIZING EFFECTS

### GREATER POTENTIAL FOR FAILED STATES AND THE GROWTH OF TERRORISM

Many developing countries do not have the government and social infrastructures in place to cope with the types of stressors that could be brought on by global climate change.

When a government can no longer deliver services to its people, ensure domestic order, and protect the nation's borders from invasion, conditions are ripe for turmoil, extremism and terrorism to fill the vacuum. Lebanon's experience with the terrorist group Hezbollah and the Brazilian government's attempts to reign in the slum gang First Capital Command [12] are both examples of how the central governments' inability to provide basic services has led to strengthening of these extra-governmental entities.

### MASS MIGRATIONS ADD TO GLOBAL TENSIONS

The reasons for mass migrations are very complex. However, when water or food supplies shift or when conditions otherwise deteriorate (as from sea level rise, for example), people will likely move to find more favorable conditions [13]. Although climate change may force migrations of workers due to economic conditions, the greatest concern will be movement of asylum seekers and refugees who due to ecological devastation become settlers:

- By 2025, 40 percent of the world's population will be living in countries experiencing significant water shortages [14].
- Over the course of this century, sea level rise could potentially cause the displacement of tens of millions of people from low-lying areas such as Bangladesh [15].

Migrations in themselves do not necessarily have negative effects, although taken in the context of global climate change a net benefit is highly unlikely. Three types of migration patterns occur.

## ADMIRAL T. JOSEPH LOPEZ, USN (Ret.)

*Former Commander-in-Chief, U.S. Naval Forces Europe and of Allied Forces, Southern Europe*

### ON CLIMATE CHANGE AND THE CONDITIONS FOR TERRORISM

Some Americans believe we don't need to worry about climate change for decades. They say the issue isn't as urgent as the war on terror. Adm. Lopez, the retired top NATO commander in Bosnia, has a different take. He sees a strong connection between the two.

"Climate change will provide the conditions that will extend the war on terror," Adm. Lopez said.

"You have very real changes in natural systems that are most likely to happen in regions of the world that are already fertile ground for extremism," Adm. Lopez said. "Droughts, violent weather, ruined agricultural lands—those are the kinds of stresses we'll see more of under climate change."

Those changes in nature will lead to changes in society. "More poverty, more forced migrations, higher unemployment. Those conditions are ripe for extremists end terrorists."

In the controversial war on terrorism, Adm. Lopez noted, there is general agreement on at least one thing: It's best to stop terrorism before it develops. "In the long term, we want to address the underlying conditions that terrorists seek to exploit. That's what we'd like to do, and it's a consensus issue—we all want to do that. But climate change prolongs those conditions. It makes them worse."

"Dealing with instability and how you mitigate that leads to questions about the role U.S. security forces can play," Adm. Lopez added. "What can we do to alleviate the problems of instability in advance? And keep in mind this will all be under a challenged resource situation. This is very complicated. Of course, the military can be a catalyst for making this happen, but it can't do it all. This is also about economics, politics, and diplomacy.

"In the military, we've often run into problems associated with what we call 'stovepipes,' where each branch of the service has its own way of doing things. And we've learned that stovepipes don't work well. We have to take the same approach with our government, to ensure that the many agencies are working together. In those cases where we do get involved, the task should not automatically be the responsibility of the U.S. military."

He also described other layers of complexity. Even in those cases where the U.S. may choose to embrace such a role, the best solutions may require a nongovernmental component. "If you don't include economists or far-thinking, out-of-the-box business people in this, you'll get shortchanged." He also said the U.S. "can't imply that we'll do this all alone. We need to make sure we don't give that impression. The same forces of economics, business, politics, diplomacy, and military and security interests can function to build coalitions in order to maintain stability when challenged by dramatic climate change."

"Climate change will provide the conditions that will extend the war on terror."

The greatest concern will be movement of asylum seekers and refugees who due to ecological devastation become settlers...

Some migrations take place within countries, adding to a nation's political stress, causing economic upheaval—positive and negative—and distracting from other issues. As a developed nation, the U.S. was able to absorb the displacement of people from the Gulf Coast in the wake of Hurricane Katrina without suffering economic or political collapse, but not without considerable turmoil.

Some migrations cross international borders. Environmental degradation can fuel migrations in less developed countries, and these migrations can lead to international political conflict. For example, the large migration from Bangladesh to India in the second half of the last century was due largely to loss of arable land, among other environmental factors. This affected the economy and political situation in the regions of India that absorbed most of this population shift and resulted in violence between natives and migrants [16].

A third form of migration involves not only crossing international borders but moving across vast regions while doing so. Since the 1960s, Europe has experienced this kind of "south to north" migration, with an influx of immigrants from Africa and Asia. The shift in demographics has created racial and religious tensions in many European countries, as evidenced in the 2005 civil unrest in France.

### POTENTIAL ESCALATION OF CONFLICTS OVER RESOURCES

To live in stability, human societies need access certain fundamental resources, the most important of which are water and food. The lack, or mismanagement, of these resources can undercut the stability of local populations; it can affect regions on a national or international scale.

Disputes over key resources such as water do not automatically trigger violent outcomes, and no recent wars have been waged solely over water resources. In areas with a strong government and societal cohesiveness, even tense disputes and resource crises can be peacefully overcome. In fact, in recent years, arguments have been made that multinational cooperation over precious water resources has been more an instrument of regional peace than of war [17].

Nevertheless, resource scarcity always has the potential to be a contributing factor to conflict and instability in areas with weak and weakly supported governments [19]. In addition, there is always the potential for regional fighting to spread to a national or international scale. Some recent examples include: the 1994 genocide in Rwanda that was furthered by violence over agricultural resources; the situation in Darfur, Sudan, which had land resources at its root and which is increasingly spilling over into neighboring Chad; the 1970s downfall of Ethiopian Emperor Haile Selassie through his government's inability ro respond to food shortages; and the 1974 Nigerian coup that resulted largely from an insufficient response to famine [19].

Whether resource scarcity proves to be the impetus for peaceful cooperation or an instigator of conflict in the future remains to be seen. Regions that are already water scarce (such as Kuwait, Jordan, Israel, Rwanda, Somalia, Algeria, and Kenya) may be forced to confront this choice as climate change exacerbates their water scarcity.

# REGIONAL IMPACTS OF CLIMATE CHANGE

## REGIONAL IMPACTS OF CLIMATE CHANGE

# AFRICA

## VULNERABLE TO CLIMATE CHANGE IMPACTS

Africa's importance to U.S. national security can no longer be ignored. Indeed, with the recent establishment of a U.S. African Command, the U.S. has underscored Africa's strategic importance. Its weak governments and the rising presence of terrorist groups make Africa important to the fight against terrorism. Moreover, Africa is also of strategic value to the U.S. as a supplier of energy; by 2015, it will supply 25 to 40 percent of our oil, and it will also be a supplier of strategic minerals such as chrome, platinum, and manganese.

Such changes will add significantly to existing tensions and can facilitate weakened governance, economic collapses, massive human migrations, and potential conflicts.

Reductions in soil moisture and further loss of arable land may be the most significant of the projected impacts of climate change in Africa. At the same time, extreme weather events are likely to increase. These expected changes portend reduced supplies of potable water and food production in key areas. Such changes will add significantly to existing tensions and can facilitate weakened governance, economic collapses, massive human migrations, and potential conflicts. In Somalia, for example, alternating droughts and floods led to migrations of varying size and speed and prolonged the instability on which warlords capitalized.

Increased political instability in Africa potentially adds additional security requirements for the U.S. in a number of ways. Stability operations, ranging from humanitarian direct delivery of goods and the protection of relief workers, to the establishment of a stable and reconstructed state, can place heavy demands on the U.S. military. While the nature of future stability operations is a matter of speculation, historically some stability operations have involved significant military operations and casualties. Political instability also makes access to African trade and resources, on which the U.S. is reliant for both military and civilian uses, a riskier proposition.

### UNSTABLE GOVERNMENTS AND TERRORIST HAVENS

Africa is increasingly crucial in the ongoing battle against civil strife, genocide, and terrorism. Numerous African countries and regions already suffer from varying degrees of famine and civil strife. Darfur, Ethiopia, Eritrea, Somalia, Angola, Nigeria, Cameroon, Western Sahara—all have been hit hard by tensions that can be traced in part to environmental causes. Struggles that appear to be tribal, sectarian, or nationalist in nature are often triggered by reduced water supplies or reductions in agricultural productivity.

The challenges Africa will face as a result of climate change may be massive, and could present serious threats to even the most stable of governments. Many African nations can

## GENERAL CHARLES F. "CHUCK" WALD, USAF (Ret.)

*Former Deputy Commander, Headquarters U.S. European Command (USEUCOM)*

### ON CLIMATE CHANGE IN AFRICA

When asked why Americans should be interested in African security issues, retired Air Force Gen. Chuck Wald gave a number of reasons.

"We ought to care about Africa because we're a good country," Gen. Wald said. "We have a humanitarian character; it's one of our great strengths, and we shouldn't deny it. Some may be tempted to avert their eyes, but I would hope we instead see the very real human suffering taking place there. We should be moved by it, challenged by it. Even in the context of security discussions, I think these reasons matter, because part of our security depends on remaining true to our values.

"There are exotic minerals found only in Africa that have essential military and civilian uses," Gen. Wald continued. "We import more oil from Africa than the Middle East—probably a shock to a lot of people—and that share will grow. Africa could become a major exporter of food.

"My view is that we'll be drawn into the politics of Africa, to a much greater extent than in the past. A lot of Americans today would say Africa is an optional engagement. I don't think that's the case, even today, but it certainly won't be in the future."

To show how climate change can worsen conditions that are already quite desperate, Gen. Wald described a trip to Nigeria.

"We landed in Lagos late in the afternoon," Gen. Wald said. "This is a city, now, with roughly 17 million people. The best way to describe our drive from the airport to the hotel is that it reminded me of a 'Mad Max' movie. There were massive numbers of people on the roads, just milling around. There were huge piles of trash. There were fires along the roadside and in the distance—huge fires. It was just short of anarchy.

"That's the situation today. Even in a time of relative stability, there is very little civil governance, and very little ability to serve huge numbers of people with basics like electricity, clean water, health care, or education.

"If you add rising coastal waters and more extreme weather events, you then have millions of people who could be displaced. There really is no controlled place for them to go, no capacity for an organized departure, and no capacity to make new living situations. When you add in the effects of climate change, it adds to the existing confusion and desperation, and puts more pressure on the Nigerian government. It makes the possibility of conflict very real. If the delta is flooded, or if major storms damage their drilling capacity, you lose the primary source of income.

"My view is that we'll be drawn into the politics of Africa, to a much greater extent than we have in the past."

"Culturally, you have a country that is split geographically between Muslims and Christians. If migrations occur, you put real pressure on that country. It's already tense and fragile. When you exacerbate that situation with climate change effects, it's not hard to postulate on the dangers."

best be described as failed states, and many African regions are largely ungoverned by civil institutions. When the conditions for failed states increase—as they most likely will over the coming decades—the chaos that results can be an incubator of civil strife, genocide, and the growth of terrorism.

### LESS EFFECTIVE GOVERNANCE AND POTENTIAL MIGRATIONS

More than 30 percent of the world's refugees and displaced persons are African. Within the last decade, severe food shortages affected twenty-five African countries and placed as many as 200 million people "on the verge of calamity" [20].

Expected future climate change will exacerbate this problem. The Sahara desert is spreading [21], and the sub-Saharan region is expected to suffer reduced precipitation [22]. As climate changes and agricultural patterns are disrupted, the geopolitics of the future will increasingly be the politics of scarcity. Potential rainfall decreases in North Africa would likely exacerbate the problem of migration to Europe. Reduced rainfall and increasing desertificarion of the sub-Saharan region will likely also result in migrations to Europe, as well as migrations within the African continent.

...the chaos that results can be an incubator of civil strife, genocide, and the growth of terrorism.

### LAND LOSS AND WEATHER DISASTERS

Sea level rise could also result in the displacement of large numbers of people on the African continent, as more than 25 percent of the African population lives within 100 kilometers (sixty-two miles) of the coast, and six of Africa's ten largest cities are on the coast. Nigeria and Mozambique are particularly vulnerable to the effects of sea level rise and storm surges. Two cyclones in 2000 displaced 500,000 people in Mozambique and caused 950,000 people to require some form of humanitarian assistance [23]. The Niger Delta accounts for about 7.5 percent of Nigeria's land area and a population of 20 million people.

In light of the potential magnitude of the human crisis that could result from major weather-related natural disasters and the magnitude of the response and recovery efforts that would be required, stability operations carried out by international militaries will likely occur more frequently.

### HEALTH CHALLENGES WILL CONTINUE TO ESCALATE

Severe and widespread continental health issues complicate an already extremely volatile environment. Climate change will have both dir and indirect impacts on many diseases endemic to Africa such as malaria and dengue fever [24]. Increases in temperature can expand the latitude and altitude ranges for malaria, and flooding from sea level rise or severe weather events can increase the population of malaria vectors. For example, a temperature rise of 2°F can bring a malaria epidemic to Kenya. Excessive flooding is also conducive to the spread of cholera.

## VICE ADMIRAL PAUL G. GAFFNEY II, USN (Ret.)

*Former President, National Defense University; Former Chief of Naval Research and Commander, Navy Meteorology and Oceanography Command*

### ON MILITARY RESEARCH AND CLIMATE SCIENCE

The Department of Defense and the intelligence community have in the past used their immense capability for data collection and analysis to address national and international environmental questions. Retired Vice Adm. Paul G. Gaffney II says we have the capacity to do this again, this time for better understanding and monitoring of climate change.

The DoD offers equipment, talent and, as Adm. Gaffney put it, "Data, data, data."

"You will find the defense and intelligence communities have extraordinary amounts of data, and, if done in a careful and deliberate manner, data collected in the past and into the future can be made available to climate scientists," Adm. Gaffney said. "Be it imagery, other satellite records, data from Navy oceanographic ships and vehicles, surface warships and submarines, or observations collected by aircraft—you can find ways to smooth it to protect what must be protected if the raw deta cannot be released. If climate change is, in fact, a critical issue for security, then the military and intelligence communities should be specifically tasked to aggressively find ways to make their data, talent, and systems capabilities available to American efforts in understanding climate change signals.

"Most of our ships are already outfitted to collect basic atmospheric and oceanic information. U.S. military platforms are all over the world, all of the time; they become platforms of opportunity to collect data for this global issue."

Adm. Gaffney also cited staff capabilities.

"The quality of personnel from the defense and intelligence organizations is exceptional," he said. "Within the DoD, we have labs that are as good as any that exist anywhere in the world, using whatever metrics you want—papers published, patents, Nobel laureates.

"Look at the Navy ocean modelers and remote sensing experts. They worked with scientists at NASA's Jet Propulsion Lab to unlock the secrets of El Niño, using spaceborne altimetry data and new numerical ocean circulation models. The mission was a military one, but it ultimately played a role in helping us understand more about the climate."

Throughout the Cold War, the U.S. and the Soviet Union each collected data in the Arctic. Ice thickness and sub-ice ocean conditions affecting acoustics were critical security issues.

"The mission was a military one, but it ultimately played a role in helping us understand more about the climate."

After the breakup of the Soviet Union, many saw that that data could be used to determine temperature and ice condition changes over time. The two sides collaborated on ways to share and reconcile the data, and in 1996 released the Arctic Ocean Atlas to the world's scientific community. The data have advanced understanding of climate change in significant ways.

"I think there's another component to this," said Adm. Gaffney. "Defense employees [military and civilian] actually have a responsibility to the nation when they have a certain skill. They have a responsibility to share that with the public and the nation, as long as security is not compromised. They've done this in the past. And I'd love to see them able to do this more often in the future."

# ASIA

## CLIMATE CHANGE CAN AFFECT IMPORTANT U.S. STRATEGIC INTERESTS

Most climate projections indicate increasing monsoon variability, resulting in increases in both flood and drought intensity in temperate and tropical Asia [24]. Almost 40 percent of Asia's population of nearly 4 billion lives within forty-five miles of its nearly 130,000-mile-long coastline. Sea level rise, water availability affecting agricultural productivity, and increased effects of infectious disease are the primary climate effects expected to cause problems in Asia.

### SEA LEVEL RISE MAY THREATEN MILLIONS

Some of the most vulnerable regions in the world to sea level rise are in southern Asia, along the coasts of Pakistan, India, Sri Lanka, Bangladesh, and Burma; and Southeast Asia, along the coasts between Thailand and Vietnam, including Indonesia and the Philippines.

Asia, where hundreds of millions of people rely on waters from vanishing glaciers on the Tibetan plateau, could be among the hardest hit regions.

Sandy coastlines backed by densely populated, low-lying plains make the Southeast Asian region particularly vulnerable to inundation. Coastal Malaysia, Thailand, and Indonesia could all be threatened with flooding and the loss of important coastal farmlands.

The location and topography of Bangladesh make it one of the most vulnerable countries in the world to a rise in sea level. Situated at the northeastern region of South Asia on the Bay of Bengal, it is about the size of Iowa with a population of almost 150 million. It is very flat and low lying, except in the northeast and southeast regions, and has a coastline exceeding 300 miles. About 10 percent of Bangladesh is within three feet of mean sea level. Over the next century, population rise, land scarcity and frequent flooding coupled with increased storm surge and sea level rise could cause millions of people to cross the border into India. Migration across the border with India is already such a concern that India is building a fence to keep Bangladeshis out.

India and Pakistan have long, densely populated and low-lying coastlines that are very vulnerable to sea level rise and storm surge. Coastal agriculture, infrastructure, and onshore oil exploration are at risk. Possible increases in the frequency and intensity of storm surges could be disproportionately large in heavily developed coastal areas and also in low-income rural areas, particularly such low-lying cities such as Mumbai, Dhaka and Karachi.

### WATER STRESS AFFECTS ASIA'S ABILITY TO FEED ITS PEOPLE

By 2050, regions dependent on glacial melting for water may face serious consequences. Asia, where hundreds of millions of people rely on waters from vanishing glaciers on the Tibetan plateau, could be among the hardest hit regions.

Climate change has the potential to exacerbate water resource stresses in most regions of Asia [7]. Most countries in Asia will experience

## ADMIRAL JOSEPH W. PRUEHER, USN (Ret.)

*Former Commander-in-Chief of the U.S. Pacific Command (PACOM) and Former U.S. Ambassador to China*

### ON CLIMATE CHANGE IN THE PACIFIC

In a discussion of climate change issues in the Pacific region, retired Adm. Joseph Prueher first considered the issue from a singular perspective: the impact climate change may have on the region's governments and their relative stability.

Using Singapore as an example, he said, "It's a democracy, but with a very strong leadership. They've prospered, but owing to lack of space they have many restrictions we do not have. If one looks ahead to the effects of climate change, you start with the understanding that Singapore, low lying and very hot, will face more storms and more moisture. It will face coastal impacts. Those kinds of changes, in a crowded nation, create a whole set of issues that affect not just the economy and culture, but the security dynamic as well."

Adm. Prueher then shifted the conversation to the region's governments in general.

"It may well be that in very crowded nations, a stronger government is necessary in order to avoid instability," he said. "In Asia, one sees a whole line of countries with governments exercising very firm control. But when you look to the future to consider the kinds of impacts we may see—flooding, extreme weather events, real disruptions—you also have to consider some steps that we in the U.S. would think offensive. Those are steps these governments may feel they need to take in order to avoid chaos."

Referencing low-lying regions where arable land will be lost, he said, "You see mass destruction in countries where the government is not robust. When people can't cope, governing structures break down."

Adm. Prueher noted that how a government responds presents a new set of issues for American political and military leaders.

"Most of our security forces are for protecting our nation from outside, but that's not necessarily the case in the rest of the world," Adm. Prueher said. "Military personnel elsewhere are often directed internally. They focus on keeping internal order. There might be cases where the U.S. military might be in a position to help deal with the effects of climate change—with floods or the migrations that might result from them. The immediate goal would be to relieve suffering, not to preserve governments. But if you're partnering with a nation's army keeping domestic order, that can be a real challenge."

When asked about China, Adm. Prueher noted that the European Union is working to identify ways of cooperating with the Chinese on the development of clean coal technologies. And he cautioned against those in the U.S. who oppose any kind of technology exchange with China.

"Yes, China is focused heavily on growth. Yes, there is what I think is a quite remote possibility of future military conflict. And, yes, it is a real challenge to negotiate with them; one can count on them to negotiate toward what they perceive to be their own national interest," he said. "Reasonable enough. But on the issue of carbon emissions, it doesn't help us to solve our problem if China doesn't solve theirs. And that means we need to engage them on many fronts. Issues of great importance to our world will not get solved without U.S.-Chinese cooperation. I happen to like dealing with the Chinese. You may not, or you may be suspicious of them, but we need to cooperate.

"They have 1.3 billion people, 200 million of whom are under-employed or unemployed," Adm. Prueher said. "They have a great deal of pride and see themselves as a great nation. Most of what we say to enhance environmental progress in China is seen by them as a way to stop them from continuing economic growth.

"Not talking to the Chinese is not an option."

## LIEUTENANT GENERAL LAWRENCE P. FARRELL JR., USAF (Ret.)

*Former Deputy Chief of Staff for Plans and Programs, Headquarters U.S. Air Force*

### ON CLIMATE, ENERGY AND BATTLEFIELD READINESS

Retired Air Force Lt. Gen. Larry Farrell sees a great deal of uncertainty about climate change and appears willing to engage any credible scientist in discussions of discrepancies among climate models.

"You might say I'm from Missouri on this issue—you have to show me," he said. "And there is still much uncertainty and debate on this issue." Despite this, Gen. Farrell sees indications that some change is occurring.

"Clearly, there has been some warming over the past 100 years and some climate change. These changes have been accompanied by fairly significant increases in the greenhouse gases carbon dioxide and methane. If there is a connection between warming trends and greenhouse gases, our use of energy may be playing a part in this. If these trends continue into the future, the changes could well exacerbate existing social and political instabilities and create new ones. The military has the obligation to assess the potential military implications of these trends." Gen. Farrell's preference is to focus on solutions.

"If you advocate intelligent energy solutions, you'll solve this problem," Gen. Farrell said, before walking through a long list of reasons for a focus on energy.

A key concern for Gen. Farrell: battlefield readiness.

"Seventy percent of the tonnage on the battlefield is fuel," he said. "That's an amazing number. Between fuel and water, it's almost everything we take to the battlefield. Food and ammo are really quite small in comparison.

"Delivering that fuel requires secure lines of communication," Gen. Farrell said. "If you have bases nearby, you may be able to deliver it with much less risk, but that's a supply line issue. And we see in Iraq how dangerous it can be to transport fuel.

"The military should be interested in fuel economy on the battlefield," he said. "It's a readiness issue. If you can move your men and materiel more quickly, if you have less tonnage but the same level of protection and firepower, you're more efficient on the battlefield. That's a life and death issue."

Gen. Farrell talked about the challenge of focusing on long-term issues.

"Climate change is not something people can recognize," he said. "In geologic times, it's quick. But in human terms, it's still very slow. It's hard to get all of us to do something about it. And that leads me to believe we should deal with other things that are a problem today but that also get us to the heart of climate change. That's where I get to the issue of smart energy choices.

"Focus on conservation and on energy sources that aren't based in carbon. Move toward a hydrogen economy, in part because you know it will ultimately give you efficiency and, yes, profit. When you pursue these things, you build alliances along the way. That's safety. It's a benefit we see right now."

He suggested another reason as well: There are military impacts that come from our energy use.

"We're forced to be interested in parts of the world because of our energy consumption," he said. "Solving the energy problem solves a real security problem. You get to choose your points of engagement. It's like one of the things your grandmother told you. 'Don't go looking for trouble. If you find trouble, you have to deal with it—but don't go looking for it!' Well, when we go looking for oil, we're really looking for trouble."

substantial declines in agricultural productivity because of higher temperatures and more variable rainfall patterns [25]. Net cereal production in South Asia, for example, is projected to decline by 4 to 10 percent by the end of this century under the most conservative climate change projections.

But the problem isn't just water scarcity—too much water can also be a problem. By 2050, snow melting in the high Himalayas and increased precipitation across northern India are likely to produce flooding, especially in catchments on the western side of the Himalayas, in northern India, Nepal, Bangladesh, and Pakistan.

## RISING SPREAD OF INFECTIOUS DISEASE

Climate change is expected to increase the geographic range of infectious diseases such as malaria, dengue fever, and schistosomiasis and increase the risk of water-borne disease. Climate projections indicate the Asia/Pacific region as a whole is likely to become warmer and wetter in the coming decades, creating conditions more conducive to disease vectors such as mosquitoes. With the exception of east central China and the highlands of west China, much of the Asia/Pacific region is exposed to malaria and dengue or has conditions suitable for their spread. This region will continue to be a hot spot for these diseases in the decades ahead, with certain regions becoming more prone to epidemics.

# EUROPE

## THREATENED BY CLIMATE PROBLEMS FROM OTHER PARTS OF THE WORLD

Europe is getting warmer overall, northern Europe is getting wetter, and southern Europe is getting drier. (For the purposes of this report, Europe includes the western part of the former Soviet Union.)

The developed nations of Europe will likely be able to deal with the direct climate changes expected for that region, but some of the less developed nations (the Balkans, for instance) might be stressed. Europe has already experienced extreme weather events that herald potential climate change effects: the more than 35,000 deaths associated with the heat wave of 2003 are a reminder of the vulnerability of all nations to climate extremes [26]. However, the major impact on Europe from global climate change is likely to be migrations, now from the Maghreb (Northern Africa) and Turkey, and increasingly, as climate conditions worsen, from Africa.

With its shortages of water, the Mediterranean area could experience considerable strain.

### DIRECT IMPACTS: HOTTER TEMPERATURES AND RISING SEAS

Most of Europe has experienced surface air temperature increases during the twentieth century (1.44°F on average), with the largest increases over northwest Russia and the Iberian Peninsula. Temperatures in Europe since 1990 have been the warmest since records have been kept. More heat waves across all of Europe are likely to increase stress on human health and could produce an increased risk of malaria and dengue fever in southern Europe. Agricultural zones would move north, and the Mediterranean regions, especially in Spain, would suffer a greater loss of productivity.

Precipitation is expected to increase in the north but decrease in the central and eastern Mediterranean zones and south Russia, with acute water shortages projected in the Mediterranean area, especially in the summer.

### MITIGATION AND ADAPTATION TO CLIMATE CHANGE IN EUROPE

The capacity for adaptation to these changes is very high in most of prosperous, industrial Europe, but less so in lesser-developed places like the Balkans, Moldova, and the Caucasus. With its shortages of water, the Mediterranean area could experience considerable strain. In northern Europe, counrries may build higher dikes, as they have done in the past, but at a certain point that may not be sufficient, and much port and other coastal infrastructure would have to be moved further inland, at great expense. Some northern migration within Europe might be expected—the Italians already face a large Albanian immigration, and others may press north from the Balkans.

### THE PRIMARY STRATEGIC CONCERN OF EUROPEANS: MASSIVE MIGRATIONS TO EUROPE

The greater threat to Europe lies in migration of people from across the Mediterranean, from the Maghreb, the Middle East, and sub-Saharan Africa. Environmental stresses and climate change are certainly not the only factors driving migrations to Europe. However, as more people migrate from the Middle East because of water shortages and loss of their already marginal agricultural lands (as, for instance, if the Nile Delta disappears under the rising sea level), the social and economic stress on European nations will rise.

It is possible that Europeans, given their long and proximate association with the sub-Saharan African countries, may undertake more stability operations, as they have in Sierra Leone and Côte d'Ivoire. Their militaries, and in particular their navies and coast guards, would also have to increase their activities in securing their borders and in intercepting migrants moving by sea, as is now going on through the Canary Islands.

# MIDDLE EAST

## ABUNDANT OIL, SCARCE WATER AND INTERNATIONAL CONFLICT

The Middle East has always been associated with two natural resources, oil (because of its abundance) and water (because of its scarcity). The Persian Gulf contains more than half (57 percent) of the world's oil reserves, and about 45 percent of the world's natural gas reserves. And because its production costs are among the world's lowest, the Persian Gulf region is likely to remain the world's largest oil exporter for the foreseeable future. At the end of 2003, Persian Gulf countries produced about 32 percent of the world's oil. Because of its enormous oil endowment, the Middle East is one of the most strategically significant regions of the world. The security impacts of climate change on the Middle East are greatly magnified by its historical and current levels of international conflict, and competition for increasingly scarce resources may exacerbate the level of conflict. This is the region of the world in which the U.S. is most engaged militarily.

### WATER: INCREASING STRESS ON AN EXISTING SHORTAGE

In this region, water resources are a critical issue; throughout history, cultures here have flourished around particular water sources. With the population explosion underway, water will become even more critical. Of the countries in the Middle East, only Egypt, Iran, and Turkey have abundant fresh water resources. Roughly two-thirds of the Arab world depends on sources outside their borders for water. The most direct effect of climate change to be felt in the Middle East will be a reduction in precipitation. But the change will not be uniform across the region.

The flows of the Jordan and Yarmuk rivers are likely to be reduced, leading to significant water stress in Israel and Jordan, where water demand already exceeds supply. Exacerbation of water shortages in those two countries and in Oman, Egypt, Iran, and Iraq are likely to threaten conventional crop production, and salinization of coastal aquifers could further threaten agriculture in those regions.

#### SEA LEVEL RISE

Sea level rise combined with increased water demand from growing populations are likely to exacerbate saltwater intrusion into coastal fresh water aquifers, already a considerable problem for the Gaza Strip. Salinization of coastal aquifers could further threaten agriculture in these regi Additional loss of arable land and decreases in food security could encourage migration within the Middle East and Africa, and from the Middle East to Europe and elsewhere.

### INFLAMING A REGION OF POLITICAL INSTABILITY

Climate change has the porential to exacerbate tensions over water as precipitation patterns change, declining by as much as 60 percent in some areas. In addition, the region already suffers from fragile governments and infrastructures, and as a result is susceptible to natural disasters. Overlaying this is a long history of animosity among countries and religious groups. With most of the world's oil being in the Middle East and the industrialized and industrializing nations competing for this resource, the potential for escalating tensions, economic disruption, and armed conflict is great.

## GENERAL ANTHONY C. "TONY" ZINNI, USMC (Ret.)

*Former Commander-in-Chief of U.S. Central Command (CENTCOM)*

### ON CLIMATE CHANGE, INSTABILITY AND TERRORISM

A starting point in understanding this connection might be to "look at how climate change effects could drive populations to migrate," Gen. Zinni said. "Where do these people move? And what kinds of conflicts might result from their migration? You see this in Africa today with the flow of migrations. It becomes difficult for the neighboring countries. It can be a huge burden for the host country, and that burden becomes greater if the international community is overwhelmed by these occurrences.

"You may also have a population that is traumatized by an event or a change in conditions triggered by climate change," Gen. Zinni said. "If the government there is not able to cope with the effects, and if other institutions are unable to cope, then you can be faced with a collapsing state. And these end up as breeding grounds for instability, for insurgencies, for warlords. You start to see real extremism. These places act like Petri dishes for extremism and for terrorist networks."

In describing the Middle East, the former CENTCOM commander said, "The existing situation makes this place more susceptible to problems. Even small changes may have a greater impact here than they may have elsewhere. You already have great tension over water. These are cultures often built around a single source of water. So any stresses on the rivers and aquifers can be a source of conflict. If you consider land loss, the Nile Delta region is the most fertile ground in Egypt. Any losses there could cause a real problem, again because the region is already so fragile. You have mass migrations within the region, going on for many decades now, and they have been very destabilizing politically."

Gen. Zinni referenced the inevitability of climate change, with global temperatures sure to increase. But he also stressed that the intensity of those changes could be reduced if the U.S. helps lead the way to a global reduction in carbon emissions. He urged action now, even if the costs of action seem high.

"It's not hard to make the connection between climate change and instability, or climate change and terrorism."

"We will pay for this one way or another," he said. "We will pay to reduce greenhouse gas emissions today, and we'll have to take an economic hit of some kind. Or we will pay the price later in military terms. And that will involve human lives. There will be a human toll.

"There is no way out of this that does not have real costs attached to it. That has to hit home."

# THE WESTERN HEMISPHERE

## RISKS FOR THE UNITED STATES AND OUR NEIGHBORS

Latin America includes some very poor nations in Central America and in the Caribbean, and their ability to cope with a changing climate will present challenges for them and thus for the U.S. Global climate change can lead to greater intensity of hurricanes as sea surface temperatures rise, with enormous implications for the southeastern U.S., Central America, and Caribbean nations. Loss of glaciers will strain water supply in several areas, particularly Peru and Venezuela. Rising sea levels will threaten all coastal nations. Caribbean nations are especially vulnerable in this regard, with the combination of rising sea levels and increased hurricane activity potentially devastating to some island nations.

The primary security threats to the U.S. arise from the potential demand for humanitarian aid and a likely increase in immigration from neighbor states. It is important to remember that the U.S. will be dealing with its own climate change issues at the same time.

### INCREASING WATER SCARCITY AND GLACIAL MELT

The melting of glaciers at an accelerated rate in Venezuela and the Peruvian Andes is a particular concern because of the direct reliance on these glaciers for water supplies and hydroelectric power. The Peruvian plains, northeast Brazil, and Mexico, already subject to drought, will find that droughts in the future will last longer. That would lead to further land degradation and loss of food production—a blow to Latin America, which is particularly dependent on food production for subsistence, and to Brazil, whose economy is fueled by food exports.

Drought and decreased rainfall is projected to also affect the central southern U.S. That could have significant impact on food production and sources of water for millions. The High Plains (or "Ogallala") aquifer underlies much of the semi-arid west-central U.S. The aquifer provides water for 27 percent of the irrigated land in the country and supplies about 30 percent of the groundwater used for irrigation. In fact, three of the top grain-producing states—Texas, Kansas, and Nebraska—each get 70 to 90 percent of their irrigation water from the Ogallala aquifer [27]. Human-induced stresses on this groundwater have resulted in water-table declines greater than 100 feet in some areas [28]. This already difficult situation could be greatly exacerbated by a decrease in rainfall predicted for the region. Similarly, a recent study by the National Research Council on the Colorado River basin (the river is the main water source for tens of millions of people in the Southwest) predicted substantial decreases in river flow, based on higher population coupled with the climate change affects [29].

### STORMS AND SEA LEVEL RISE

In looking at the relationship between warmer temperatures and storm intensity, a panel convened by the World Meteorological Organization concluded: "It is likely that some increase in tropical cyclone peak wind-speed and rainfall

## ADMIRAL DONALD L. "DON" PILLING, USN (Ret.)

*Former Vice Chief of Naval Operations*

### ON OPERATIONAL CHALLENGES OF CLIMATE CHANGE

Retired Adm. Donald L. Pilling, former vice chief of naval operations, highlighted one of the reasons government agencies have been slow to respond to the issue of climate change.

"One of the problems in talking about this issue is that no one can give you a date by which many of the worst effects will be occurring," Adm. Pilling said. "If it's 2050, there isn't a guy in uniform today who will be wearing a uniform then. The Pentagon talks about future year plans that are six years down the road."

Still, Adm. Pilling was able to talk about the issue and the planning challenges it might offer. He enumerated a list of operational impacts, starting with the assumption that there would be increased instances of large migrations—people fleeing homelands that have felt the impacts of climate changes.

"This is key because it's easy to see how our allies can be consumed by this," Adm. Pilling said. "They won't have time to participate in exercises at sea because all of their assets will be focused on protecting the border and beaches. Europe will be focused on its own borders. There is potential for fracturing some very strong alliances based on migrations and the lack of control over borders.

"Open seas at the Arctic means you have another side of this continent exposed," he said. "Between the Canadians and us, there are a handful of ships oriented for the northernmost latitudes. But there is not much flexibility or depth there."

He said that an increase in the frequency or intensity of hurricanes could have a destabilizing effect on maintenance and the stability of ships and fleets. "It may cause you to move ships north to avoid hurricanes. If a ship's captain thinks he's in the middle of hurricane season, he's going to go out—get away from port. It impacts maintenance schedules and impacts operational structures. And that doesn't factor in the damage that hurricanes can do to our ports and maintenance facilities. We spent a few billion to restore Pascagoula after Hurricane Katrina—and we're not done yet. But at least that's an impact you can see. People can get their hands around that."

"There is potential for fracturing some very strong alliances based on migrations and the lack of control over borders."

Over time, some of the operational issues related to climate change would be increasingly difficult to resolve.

"At headquarters, they would need to be much more thoughtful about investment decisions," he said. "Why invest significant resources in bases that are in low-lying regions? Why invest in bases that may continue to be flooded? Those are tough questions to ask, but I'd ask them."

will occur if the climate continues to warm. Model studies and theory project a 3-5% increase in wind-speed per degree Celsius increase of tropical sea surface temperatures" [30]. Warming seas and their link to storm energy are especially worrisome for Central American and small Caribbean island nations that do not have the social infrastructure to deal with natural disasters.

Flooding could increase with sea level rises, especially in the low-lying areas of North America—inundation models from the University of Arizona project that a sea level rise of three feet would cause much of Miami, Fort Myers, a large portion of the Everglades, and all of the Florida Keys to disappear [31].

In the past, U.S. military forces have responded to natural disasters, and are likely to continue doing so in the foreseeable future [32]. The military was deployed to Central America after Hurricane Mitch in 1998 and to Haiti following the rains and mudslides of 2004. The U.S. military was also heavily involved in the response to Hurricane Katrina. Climate change will likely increase calls for this type of mission in the Americas in the future.

### INCREASED MIGRATION/REFUGEE FLOWS INTO THE U.S.

The greater problem for the U.S. may be an increased flow of migrants northward into the U.S. Already, a large volume of south to north migration in the Americas is straining some states and is the subject of national debate. The migration is now largely driven by economics and political instability. The rate of immigration from Mexico to the U.S. is likely to rise because the water situation in Mexico is already marginal and could worsen with less rainfall and more droughts. Increases in weather disasters, such as hurricanes elsewhere, will also stimulate migrations to the U.S. [32].

## GENERAL PAUL J. KERN, USN (Ret.)

*Former Commanding General, U.S. Army Materiel Command*

### ON WEATHER, LOGISTICS, AND THE CAUSES OF WAR

In 1989, Gen. Kern commanded a brigade based at Fort Stewart, Georgia, and was preparing to send men and materiel to Turkey in advance of NATO training exercises. Those plans were interrupted by Hurricane Hugo, which appeared headed to Savannah, the port of departure for the mission.

"We were all ready to go, but the ships involved in transport had to be sent to Norfolk," Gen. Kern said. "So we broke down the shipments that had already been assembled for delivery. We then moved our aviation assets out, and moved base families into shelters. Ultimately, the hurricane hit Charleston, and did major damage to the airbase there. That meant one of my military battalions was deployed to Charleston to help with the recovery there."

"These weren't immense challenges for us—they were things we could handle," Gen. Kern said. "But the planned training exercises—preparing us for our core military mission—were not as good as they could have been. It's a very subtle thing, but there you have it in a nutshell: Extreme weather can affect your readiness."

Looking ahead, Gen. Kern, now retired from active duty, discussed wider global trends that the military must address to achieve an optimal state of readiness. He believes "the critical factors for economic and security stability in the twenty-first century are energy, water, and the environment. These three factors need to be balanced for people to achieve a reasonable quality of life. When they are not in balance, people live in poverty, suffer high death rates, or move toward armed conflict."

The need for water illustrates the consequences of imbalance. "When water is scarce, people move until they can find adequate supply," he said. "As climate change causes shifts in accessibility to water, we observe large movements of refugees and emigration."

He said Africa offers prime examples of this, and referenced a passage from the book Transboundary Rivers, Sovereignty and Development (Anthony Turton, Peter Ashton, and Eugene Cloete, eds.), which states that "there is a vast and growing literature that cites water as a likely cause of wars in the twenty-first century, and the 15 international basins in the Southern African Development Community (SADC) are regularly named as points of tension, second only to the arid and hostile Middle East."

He quoted from a letter written to him by Anthony Turton, a soldier in the war over the Okavong River basin, who wrote that "to serve one's country on the field of battle is truly noble, but to serve as a peace-builder is truly great." Turton also wrote that in his new role of restoring river basins, he has "found personal peace."

Gen. Kern also cited the late Nobel Laureate, Dr. Rick Smalley, of Rice University, who often lectured on the world's top 10 problems. Smalley listed energy, water, food, and the environment at the top of his list.

"While the military community has not focused on these issues, we often find ourselves responding to a crisis created by the loss of these staples, or by a conflict over claims to one or more of them," Gen. Kern said. "In my view, therefore, military planning should view climate change as a threat to the balance of energy access, water supplies, and a healthy environment, and it should require a response. Responding after the fact with troops—after a crisis occurs—is one kind of response. Working to delay these changes—to accommodate a balance among these staples—is, of course, another way."

"Military planning should view climate change as a threat to the balance of energy access, water supplies, and a healthy environment, and it should require a response."

# DIRECT IMPACTS ON MILITARY SYSTEMS, INFRASTRUCTURE, AND OPERATIONS

# DIRECT IMPACTS ON MILITARY SYSTEMS, INFRASTRUCTURE, AND OPERATIONS

Climate change will stress the U.S. military by affecting weapons systems and platforms, bases, and military operations. It also presents opportunities for constructive engagement.

## WEAPONS SYSTEMS AND PLATFORMS

Operating equipment in extreme environmental conditions increases maintenance requirements—at considerable cost—and dramatically reduces the service life of the equipment. In Iraq, for instance, sandstorms have delayed or stopped operations and inflicted tremendous damage to equipment. In the future, climate change—whether hotter, drier, or wetter—will add stress to our weapons systems.

A stormier northern Atlantic would have implications for U.S. naval forces [34]. More storms and rougher seas increase transit times, contribute to equipment fatigue and hamper flight operations. Each time a hurricane approaches the U.S. East Coast, military aircraft move inland and Navy ships leave port. Warmer temperatures in the Middle East could make operations there even more difficult than they are today. A Center for Naval Analyses study showed that the rate at which U.S. carriers could launch aircraft was limited by the endurance of the flight deck crew during extremely hot weather [34].

## BASES THREATENED BY RISING SEA LEVELS

During the Cold War, the U.S. established and maintained a large number of bases throughout the world. U.S. bases abroad are situated to provide a worldwide presence and maximize our ability to move aircraft and personnel. Climate change could compromise some of those bases. For example, the highest point of Diego Garcia, an atoll in the southern Indian Ocean that serves as a major logistics hub for U.S. and British forces in the Middle East, is only a few feet above sea level. As sea level rises, facilities there will be lost or will have to relocated. Although the consequences to military readiness are not insurmountable, the loss of some forward bases would require longer range lift and strike capabilities and would increase the military's energy needs.

Closer to home, military bases on the eastern coast of the United States are vulnerable to hurricanes and other extreme weather events. In 1992, Hurricane Andrew ravaged Homestead Air Force Base in Florida so much that it never reopened; in 2004 Hurricane Ivan knocked out Naval Air Station Pensacola for almost a year. Increased storm activity or sea level rise caused by future climate change could threaten or destroy essential base infrastructure. If key military bases are degraded, so, too, may be the readiness of our forces.

Climate change—whether hotter, drier, or wetter—will add stress to our weapons systems.

## MILITARY OPERATIONS

Severe weather has a direct effect on military readiness. Ships and aircraft operations are made more difficult; military personnel themselves must evacuate or seek shelter. As retired

Army Gen. Paul Kern explained of his time dealing with hurricanes in the U.S. Southern Command: "A major weather event becomes a distraction from your ability to focus on and execute your military mission."

In addition, U.S. forces may be required to be more engaged in stability operations in the future as climate change causes more frequent weather disasters such as hurricanes, flash floods, and extended droughts.

### THE ARCTIC: A REGION OF PARTICULAR CONCERN

A warming Arctic holds great implications for military operations. The highest levels of planetary warming observed to date have occurred in the Arctic, and projections show the high northern latitudes warming more than any other part of the earth over the coming century. The Arctic, often considered to be the proverbial "canary" in the earth climate system, is showing clear signs of stress [33].

The U.S. Navy is concerned about the retreat and thinning of the ice canopy and its implications for naval operations. A 2001 Navy study concluded that an ice-free Arctic will require an "increased scope of naval operations" [35]. That increased scope of operations will require the Navy to consider weapon system effectiveness and various other factors associated with operating in this environment. Additionally, an Arctic with less sea ice could bring more competition for resources, as well as more commercial and military activity that could further threaten an already fragile ecosystem.

As extreme weather events becomes more common, so do the threats to our national electricity supply.

### DEPARTMENT OF DEFENSE ENERGY SUPPLIES ARE VULNERABLE TO EXTREME WEATHER

The DoD is almost completely dependent on electricity from the national grid to power critical missions at fixed installations and on petroleum to sustain combat training and operations. Both sources of energy and their distribution systems are susceptible to damage from extreme weather.

The national electric grid is fragile and can be easily disrupted. Witness the Northeast Blackout of 2003, which was caused by trees falling onto power lines in Ohio. It affected 50 million people in eight states and Canada, took days to restore, and caused a financial loss in the United States estimated to be between $4 billion and $10 billion [36]. People lost water supplies, transportation systems, and communications systems (including Internet and cell phones). Factories shut down, and looting occurred.

As extreme weather events becomes more common, so do the threats to our national electricity supply.

One approach to securing power to DoD installations for critical missions involves a combination of aggressively applying energy efficiency technologies to reduce the critical load (more mission, less energy); deploying renewable energy sources; and "islanding" the installation from the national grid. Islanding allows power generated on the installations to flow two ways—onto the grid when there is excess production and from the grid when the load exceeds local generation. By pursuing these actions to improve resiliency of mission, DoD would become an early adopter of technologies that would help transform the grid, reduce our load, and expand the use of renewable energy.

For deployed systems, the DoD pays a high price for high fuel demand. In Iraq, significant combat forces are dedicated to moving fuel and protecting fuel supply lines. The fuel delivery situation on the ground in Iraq is so limited

that that the Army has established a "Power Surety Task Force" to help commanders of forward operating bases cut the number of fuel convoys by using energy more efficiently. Maj. Gen. Richard Zilmer, USMC, commander of the multinational force in the Anbar province of Iraq, asked for help in August 2006. His request was for renewable energy systems. According to Gen. Zilmer, "reducing the military's dependence on fuel for power generation could reduce the number of road-bound convoys ... 'Without this solution [renewable energy systems], personnel loss rates are likely to continue at their current rate. Continued casualty accumulation exhibits potential to jeopardize mission success....'" Along a similar vein, Lt. Gen. James Mattis, while commanding general of the First Marine Division during Operation Iraqi Freedom, urged: "Unleash us from the tether of fuel."

Energy-efficiency technologies, energy conservation practices and renewable energy sources are the tools forward bases are using to stem their fuel demand and reduce the "target signature" of their fuel convoys.

Numerous DoD studies dating from the 2001 Defense Science Board report "More Capable Warfighting Through Reduced Fuel Burden" have concluded that high fuel demand by combat forces detracts from our combat capability, makes our forces more vulnerable, diverts combat assets from offense to supply line protection, and increases operating costs. Nowhere are these problems more evident than in Iraq, where every day 2.4 million gallons of fuel is moved through dangerous territory, requiring protection by armored combat vehicles and attack helicopters [37].

DoD planners estimate that it costs $15 to deliver one gallon of fuel from its commercial supplier to the forward edge of the battlefield and about $26 to deliver a gallon of fuel from an airborne tanker, not counting the tanker aircraft cost. Furthermore, DoD's procedures for determining the types of systems it needs do not take these fuel burden considerations into account. DoD should require more efficient combat systems and should include the actual cost of delivering fuel when evaluating the advantages of investments in efficiency [38, 39].

... reducing the military's dependence on fuel for power generation could reduce the number of road-bound convoys ...

DoD should have an incentive to accurately account for the cost of moving and protecting fuel and to invest in technologies that will provide combat power more efficiently. Deploying technologies that make our forces more efficient also reduces greenhouse gas emissions. The resulting technologies would make a significant contribution to the vision President Bush expressed in his State of the Union speech when he said, "America is on the verge of technological breakthroughs that will ... help us to confront the serious challenge of global climate change."

Given the human and economic cost of delivering fuel to combat forces and the almost total dependence on the electric grid for critical missions, DoD has strong operational economic incentives to aggressively pursue energy efficiency in its combat systems and its installations. By investing at levels commensurate with its interests, DoD would become an early adopter of innovative technologies and could stimulate others to follow.

### ENGAGEMENT OPPORTUNITIES

Climate change threats also create opportunities for constructive engagement such as stability operations and capacity building. The U.S. military helped deliver relief to the victims of

the 2005 Indian Ocean tsunami because it is the only institution capable of rapidly delivering personnel and materiel anywhere in the world on relatively short notice. DoD Directive 3000.05, issued in 2006, provides the mandate to conduct military and civilian stability operations in peacetime as well as conflict to maintain order in states and regions. The Combatant Command's Theater Security Cooperation Program, which seeks to engage regional states, could be easily focused on climate change mitigation and executed in concert with other U.S. agencies through U.S. embassy country teams. The objective would be to build the host nation military's capabilities and capacity to support civilian government agencies. It also enhances good governance and promotes stability, making failed states and terrorist incursion less likely. Because many climate change problems cross borders, it could also promote regional communication and cooperation.

If the frequency of natural disasters increases with climate change, future military and political leaders may face hard choices about where and when to engage. Deploying troops affects readiness elsewhere; choosing not to may affect alliances. And providing aid in the aftermath of a catastrophic event or natural disaster can help retain stability in a nation or region, which in turn could head off U.S. military engagement in that region at a later date.

## ADMIRAL FRANK "SKIP" BOWMAN, USN (Ret.)

*Former Director, Naval Nuclear Propulsion Program; Former Deputy Administrator-Naval Reactors, National Nuclear Security Administration*

### ON CLIMATE CHANGE, ENERGY, AND NATIONAL SECURITY

Adm. Bowman's more than thirty-eight years of naval service in the nuclear submarine community lead him to these thoughts: "Our nuclear submarines operate in an unforgiving environment. Our Navy has recognized this environment and has mitigated the risk of reactor and undersea operations through a combination of: a) careful selection of motivated, intelligent people whom we train and qualify to the highest standards; b) rigorous quality assurance of component design and manufacturing; c) verbatim compliance with strict rules of operation; d) routine examination of all aspects of reactor and submarine operations; and, e) a constant sharing of the lessons we learn through these processes. These components lead to a defense in depth against a very low probability, but high consequence event. We should begin planning for a similar approach in dealing with potential climate change effects on our national security."

Adm. Bowman notes that today, a raging debate is underway over a potential set of climate-induced global changes that could have a profound impact on America's national security interests. Our Military Advisory Board has heard the arguments, some depicting near-doomsday scenarios of severe weather and oceanic changes exacerbated by man-made emissions of greenhouse gases to our environment, others depicting a much less severe outcome as merely one in many observed cyclic weather patterns over time, with virtually no man-made component.

Adm. Bowman concludes that regardless of the probability of the occurrence, the projected weather-driven global events could be dire and could adversely affect our national security and military options significantly. He therefore argues that the prudent course is to begin planning, as we have in submarine operations, to develop a similar defense in depth that would reduce national security risks even if this is a low probability event, given the potential magnitude of the consequences. He feels that as the debate over cause, effect, and magnitude continues, we in the military should begin now to take action to provide a resilient defense against the effects of severe climate change, not only within our own borders, but also to provide resiliency to those regions of unrest and stress that already are threatening our national security today.

> "Our nuclear submarines operate in an unforgiving environment. Our Navy has recognized this environment and has mitigated the risk. ... We should begin planning for a similar approach in dealing with potential climate change effects on our national security."

The admiral further believes that "our national security is inextricably linked to our country's energy security." Thoughtful national policy is required as we debate a correct course of future energy policy. International participation is necessary for this global issue. Adm. Bowman firmly believes that "energy and economic security—key components of our national security—must be undergirded by alternative forms of energy available indigenously and from countries whose values are not at odds with our own. As our economy and GDP have grown, so have our energy needs. This demand for energy strains available supplies: energy sources used for one purpose, such as electricity generation, are not available for other needs. Natural gas used for electricity is not available as feedstock for many industries that depend on it, like the chemical industry, the fertilizer industry, and the plastics industry. Short-term decisions made over the past decade to build cheap gas generation placed an unsustainable demand on natural gas and has resulted in hundreds of thousands of U.S. jobs moving offshore."

Adm. Bowman warns that this interdependence between energy policy and national security must be viewed over the long haul as the country addresses global climate change. "Coal and nuclear electricity generation remain the obvious choices for new U.S. generation. However, to meet the concerns over measured and measurable increases in $CO_2$ concentrations in our atmosphere and their potential effect on climate, the country, as a matter of national urgency, must develop the technologies to capture and sequester $CO_2$ from coal generation. This technology is not available today on a commercial scale, and the lead time for its development is measured in tens of years, not months.

Therefore, Adm. Bowman argues, we should begin developing plans to shore up our own defenses against the potentially serious effects of climate, regardless of the probability of that occurrence, while making more resilient those countries ill-prepared today to deal with that potential due to disease, poor sanitation, lack of clean water, insufficient electricity, and large coastal populations. In doing so, these plans must recognize the interdependency of energy and security.

## WEATHER AND WARFARE

An increase in extreme weather can make the most demanding of tasks even more challenging.

Increases in global temperatures will increase the likelihood of extreme weather events, including remperature extremes, precipitation events, and intense tropical cyclone activity [7].

With this in mind, we ask the obvious: How does extreme weather affect warfare?

The impacts are significant. There are countless historical examples of how weather events have affected the outcome of a conflict.

- Typhoons (Divine Wind) twice saved Japan from invasion by Kublai Khan and his Mongol horde.
- North Sea gales badly battered the Spanish Armada in 1588 when Sir Francis Drake defeated it, saving England from invasion.

An increase in extreme weather can make the most demanding of tasks even more challenging.

- The severe and unpredictable Russian winter has defeared three invading armies: Charles XII of Sweden in 1708, Napoleon in 1812 and Hitler in 1941.
- During the American Revolution, George Washington would have been surrounded at the Battle of Long Island had adverse winds not prevented the British from landing and cutting him off.
- Hardships from a severe drought in 1788 are thought to be the spark that caused the French Revolution.
- Napoleon was defeated at the Battle of Waterloo in large part because a torrential downpour obscured visibility and delayed the French attack.

Though technology allows us to overcome many obstacles, weather still poses great threats to successful military operations on the land, sea, or in the air.

- During World War II, Typhoon Cobra capsized three destroyers, a dozen more ships were seriously damaged and 793 men died. This natural disaster, called the Navy's worst defeat in open seas in World War II, killed nearly a third as many as in the attack on Pearl Harbor.
- Many know that D-Day awaited the right weather before it began. Many don't know that a freak storm destroyed floating docks shortly beforehand, almost canceling the invasion.
- During the 1991 Persian Gulf War, heavy winds prevented Saddam Hussein from launching Scud missiles at Israel and coalition forces.
- During the Persian Gulf War and the Iraq war, sandstorms delayed or stopped operarions and did tremendous damage to equipment. In March 2003, the entire invasion of Iraq was stalled for three days because of a massive sandstorm.

These examples are not meant to suggest that weather changes will put the American military at a disadvantage. They do, however, help illustrate ways in which climate change can add new layers of complexity to military operations. An increase in extreme weather can make the most demanding of tasks even more challenging.

# FINDINGS AND RECOMMENDATIONS

# FINDINGS AND RECOMMENDATIONS

This report is intended to advance a more rigorous national and international dialogue on the impacts of climate change on national security. We undertook this analysis for the primary purpose of presenting the problem and identifying first-order solutions. We therefore keep this list of findings and recommendations intentionally brief. We hope it will stimulate further discussion by the public and a more in-depth analysis by those whose job it is to plan for our national security.

## FINDINGS

**Finding 1:**
**Projected climate change poses a serious threat to America's national security.**

Potential threats to the nation's security require careful study and prudent planning—to counter and mitigate potential detrimental outcomes. Based on the evidence presented, the Military Advisory Board concluded that it is appropriate to focus on the serious consequences to our national security that are likely from unmitigated climate change. In already-weakened states, extreme weather events, drought, flooding, sea level rise, retreating glaciers, and the rapid spread of life-threatening diseases will themselves have likely effects: increased migrations, further weakened and failed states, expanded ungoverned spaces, exacerbated underlying conditions that terrorist groups seek to exploit, and increased internal conflicts. In developed countries, these conditions threaten to disrupt economic trade and introduce new security challenges, such as increased spread of infectious disease and increased immigration.

Overall, climate change has the potential to disrupt our way of life and force changes in how we keep ourselves safe and secure by adding a new hostile and stressing factor into the national and international security environment.

**Finding 2:**
Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world.

Many governments in Asia, Africa, and the Middle East are already on edge in terms of their ability to provide basic needs: food, water, shelter and stability. Projected climate change will exacerbate the problems in these regions and add to the problems of effective governance. Unlike most conventional security threats that involve a single entity acting in specific ways at different points in time, climate change has the potential to result in multiple chronic conditions, occurring globally within the same time frame. Economic and environmental conditions in these already fragile areas will further erode as food production declines, diseases increase, clean water becomes increasingly scarce, and populations migrate in search of resources. Weakened and failing governments, with an already thin margin for survival, foster the conditions for internal conflict, extremism, and movement toward increased authoritarianism and radical ideologies. The U.S. may be drawn more frequently into these situations to help to provide relief, rescue, and logistics, or to stabilize conditions before conflicts arise.

Because climate change also has the potential to create natural and humanitarian disasters on a scale far beyond those we see today, its consequences will likely foster political instability

where societal demands exceed the capacity of governments to cope. As a result, the U.S. may also be called upon to undertake stability and reconstruction efforts once a conflict has begun.

**Finding 3:**
**Projected climate change will add to tensions even in stable regions of the world.**

Developed nations, including the U.S. and Europe, may experience increases in immigrants and refugees as drought increases and food production declines in Africa and Latin America. Pandemic disease caused by the spread of infectious diseases and extreme weather events and natural disasters, as the U.S. experienced with Hurricane Katrina, may lead to increased domestic missions for U.S. military personnel—lowering troop availability for other missions and putting further stress on our already stretched military, including our Guard and Reserve forces.

Our current National Security Strategy, released in 2002 and updated in 2006, refers to globalization and other factors that have changed the security landscape. It cites, among other factors, "environmental destruction, whether caused by human behavior or cataclysmic mega-disasters such as floods, hurricanes, earthquakes or tsunamis. Problems of this scope may overwhelm the capacity of local authorities to respond, and may even overtax national militaries, requiring a larger international response. These challenges are not traditional national security concerns, such as the conflict of arms or ideologies. But if left unaddressed they can threaten national security."

In addition to acknowledging the national securiry implications of extreme weather and other environmental factors, the National Security Strategy indicates that the U.S. may have ro intervene militarily, though it clearly states that dealing with the effects of these evenrs should not be the role of the U.S. military alone.

Despite the language in our current National Security Strategy, there is insufficient planning and preparation on the operational level for future environmental impacts. However, such planning can readily be undertaken by the U.S. military in cooperation with the appropriate civilian agencies, including the State Department, the United States Agency for International Development, and the intelligence community.

**Finding 4:**
**Climate change, national security, and energy dependence are a related set of global challenges.**

As President Bush noted in his 2007 State of the Union speech, dependence on foreign oil leaves us more vulnerable to hostile regimes and terrorists, and clean domestic energy alternatives help us confront the serious challenge of global climate change. Because the issues are linked, solutions to one affect the others. Technologies that improve energy efficiency also reduce carbon intensity and carbon emissions.

## RECOMMENDATIONS

**Recommendation 1:**
**The national security consequences of climate change should be fully integrated into national security and national defense strategies.**
As military leaders, we know we cannot wait for certainty. Failing to act because a warning isn't precise is unacceptable. Numerous parts of the U.S. government conduct analyses of various aspects of our national security situation covering different time frames and at varying levels of detail. These analyses should consider the consequences of climate change.

The intelligence community should incorporate climate consequences into its National Intelligence Estimate. The National Security Strategy should directly address the threat of climate change to our national security interests. It also should include an assessment of the national security risks of climate change and direct the U.S. government to take appropriate preventive efforts now.

The National Security Strategy and the National Defense Strategy should include appropriate guidance to military planners to assess risks to current and future missions of projected climate change, guidance for updating defense plans based on these assessments, and the capabilities needed to reduce future impacts. This guidance should include appropriate revisions to defense plans, including working with allies and partners, to incorporate climate mitigation strategies, capacity building, and relevant research and development.

The next Quadrennial Defense Review should examine the capabilities of the U.S. military to respond to the consequences of climate change, in particular, preparedness for natural disasters from extreme weather events, pandemic disease events, and other missions the U.S. military may be asked to support both at home and abroad. The capability of the National Guard and Reserve to support these missions in the U.S. deserve special attention, as they are already stretched by current military operations.

The U.S. should evaluate the capacity of the military and other institutions to respond to the consequences of climate change. All levels of government—federal, state, and local—will need to be involved in these efforts to provide capacity and resiliency to respond and adapt.

Scientific agencies such as the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA) and the United States Geologic Survey (USGS) should also be brought into the planning processes.
The defense and intelligence communities should conduct research on global climate and monitor global climate signals to understand their national security implications. Critical security-relevant knowledge about climate change has come from the partnership between environmental scientists and the defense and intelligence communities. That partnership, vibrant in the 1990s, should be revived.

**Recommendation 2:**
**The U.S. should commit to a stronger national and international role to help stabilize climate changes at levels that will avoid significant disruption to global security and stability.**
All agencies involved with climate science, treaty negotiations, energy research, economic policy, and national security should participate in an interagency process to develop a deliberate policy to reduce future risk to national security

from climate change. Actions fall into two main categories: mitigating climate change to the extent possible by setting targets for long-term reductions in greenhouse gas emissions and adapting to those effects that cannot be mitigated. Since this is a global problem, it requires a global solution with multiple relevant instruments of government contributing.

While it is beyond the scope of this study to recommend specific solutions, the path to mitigating the worst security consequences of climate change involves reducing global greenhouse gas emissions. Achieving this outcome will also require cooperation and action by many agencies of government.

**Recommendation 3:**
**The U.S. should commit to global partnerships that help less developed nations build the capacity and resiliency to better manage climate impacts.**

Some of the nations predicted to be most affected by climate change are those with the least capacity to adapt or cope. This is especially true in Africa, which is becoming an increasingly important source of U.S. oil and gas imports. Already suffering tension and stress resulting from weak governance and thin margins of survival due to food and water shortages, Africa would be yet further challenged by climate change. The proposal by DoD to establish a new Africa Command reflects Africa's emerging strategic importance to the U.S., and with humanitarian catastrophes already occurring, a worsening of conditions could prompt further U.S. military engagement. As a result, the U.S. should focus on enhancing the capacity of weak African governments to better cope with societal needs and to resist the overtures of well-funded extremists to provide schools, hospitals, health care, and food.

The U.S. should target its engagement efforts, through regional military commanders and other U.S. officials, toward building capacity to mitigate destabilizing climate impacts. For example, regional commanders have routinely used such engagement tools as cooperation on disaster preparedness to help other nations develop their own ability to conduct these efforts.

Cooperative engagement has the potential to reduce the likelihood of war fighting. As Gen. Anthony C. (Tony) Zinni (Ret.) has said: "When I was commander of CENTCOM, I had two missions: engagement and war fighting: If I do engagement well, I won't have to do war fighting." The U.S. cannot do this alone; nor should the military be the sole provider of such cooperative efforts. But the U.S. can lead by working in cooperation with other nations. Such efforts promote greater regional cooperation, confidence building and the capacity of all elements of national influence to contribute to making nations resilient to the impacts of climate change.

**Recommendation 4:**
**The Department of Defense should enhance its operational capability by accelerating the adoption of improved business processes and innovative technologies that result in improved U.S. combat power through energy efficiency.**

DoD should require more efficient combat systems and should include the actual cost of delivering fuel when evaluating the advantages of investments in efficiency. Numerous DoD studies dating from the 2001 Defense Science Board report "More Capable Warfighting Through Reduced Fuel Burden" have concluded that high fuel demand by combat forces detracts from our combat capability, makes our forces more vulnerable, diverts combat assets from offense to supply line protection, and increases operating costs. Nowhere are these problems more evident than

in Iraq, where every day 2.4 million gallons of fuel is moved through dangerous territory, requiring protection by armored combat vehicles and attack helicopters.

Deploying technologies that make our forces more efficient also reduces greenhouse gas emissions. DoD should invest in technologies that will provide combat power more efficiently. The resulting technologies would make a significant contribution to the vision President Bush expressed in his State of the Union when he said, "America is on the verge of technological breakthroughs that ... will help us to confront the serious challenge of global climate change."

**Recommendation 5:**
**DoD should conduct an assessment of the impact on U.S. military installations worldwide of rising sea levels, extreme weather events, and other possible climate change impacts over the next 30 to 40 years.**

As part of prudent planning, DoD should assess the impact of rising sea levels, extreme weather events, drought, and other climate impacts on its infrastructure so its installations and facilities can be made more resilient.

Numerous military bases, both in the U.S. and overseas, will be affected by rising sea levels and increased storm intensity. Since World War II, the number of overseas bases has diminished, and since the Base Realignment and Closure process began the number of stateside bases has also declined. This makes those that remain more critical for training and readiness, and many of them are susceptible to the effects of climate change. For example, the British Indian Ocean Territory island of Diego Garcia, an atoll in the southern Indian Ocean, is a major logistics hub for U.S. and British forces in the Middle East. It is also only a few feet above sea level at its highest point. The consequences of the losing places like Diego Garcia are not insurmountable, but are significant and would require advance military planning. The Kwajalein is a low-lying atoll, critical for space operations and missile tests. Guam is the U.S. gateway to Asia and could be moderately or severely affected by rising sea levels. Loss of some forward bases would require us to have longer range lift and strike capabilities and possibly increase our military's energy needs.

Military bases on the eastern coast of the U.S. are vulnerable to hurricanes and other extreme weather events. In 1992, Hurricane Andrew virtually destroyed Homestead Air Force Base in Florida. In 2004 Hurricane Ivan knocked out Naval Air Station Pensacola for almost a year. Most U.S. Navy and Coast Guard bases are located on the coast, as are most U.S. Marine Corps locations. The Army and Air Force also operate bases in low-lying or coastal areas. One meter of sea level rise would inund[illegible] much of Norfolk, Virginia, the major East Coast hub for the U.S. Navy. As key installations are degraded, so is the readiness of our forces.

# APPENDICES

# APPENDIX 1:
# BIOGRAPHIES, MILITARY ADVISORY BOARD MEMBERS

**ADMIRAL FRANK "SKIP" BOWMAN, USN (Ret.)**

*Former Director, Naval Nuclear Propulsion Program;*

*Former Deputy Administrator-Naval Reactors, National Nuclear Security Administration*

Admiral Skip Bowman was director, Naval Nuclear Propulsion, Naval Sea Systems Command. Prior assignments include deputy administrator for naval reactors in the Naval Nuclear Security Administration, Department of Energy; chief of naval personnel; and director for Political-Military Affairs and deputy director of naval operations on the Joint Staff.

He was commissioned following graduation in 1966 from Duke University. In 1973, he completed a dual master's program in nuclear engineering and naval architecture/marine engineering at the Massachusetts Institute of Technology and was elected to the Society of Sigma Xi. Admiral Bowman has been awarded the honorary degree of Doctor of Humane Letters from Duke University.

In 2005, Admiral Bowman was named president and CEO of the Nuclear Energy Institute. NEI is the policy organization for the commercial nuclear power industry. In 2006, Admiral Bowman was made an Honorary Knight Commander of the Most Excellent Order of the British Empire in recognition of his commitment in support of the Royal Navy submarines program.

**LIEUTENANT GENERAL LAWRENCE P. FARRELL JR., USAF (Ret.)**

*Former Deputy Chief of Staff for Plans and Programs, Headquarters U.S. Air Force*

Prior to his retirement from the Air Force in 1998, General Farrell served as the deputy chief of staff for plans and programs, Headquarters U.S. Air Force, Washington, D.C. He was responsible for planning, programming and manpower activities within the corporate Air Force and for integrating the Air Force's future plans and requirements to support national security objectives and military strategy.

Previous positions include vice commander, Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio, and deputy director, Defense Logistics Agency, Arlington, Virginia. He also served as deputy chief of staff for plans and programs at Headquarters U.S. Air Force in Europe. A command pilot with more than 3,000 flying hours, he flew 196 missions in Southeast Asia and commanded the 401st Tactical Fighter Wing, Torrejon Air Base, Spain. He was also the system program manager for the F-4 and F-16 weapons systems with the Air Force Logistics Command, Hill Air Force Base, Utah.

General Farrell is a graduate of the Air Force Academy with a bachelor's degree in engineering and an MBA from Auburn University. Other education includes the National War College and the Harvard Program for Executives in National Security.

General Farrell became the president and CEO of the National Defense Industrial Association in September 2001.

**VICE ADMIRAL PAUL G. GAFFNEY II, USN (Ret.)**

*Former President, National Defense University; Former Chief of Naval Research and Commander, Navy Meteorology and Oceanography Command*

Admiral Gaffney has been the Naval Research Laboratory commander and worked in a number of other science and oceanography administration assignments. He served as the 10th president of the National Defense University, and before that as chief of naval research. He also was the senior uniformed oceanography specialist in the Navy, having served as commander of the Navy Meteorology and Oceanography Command from 1994 to 1997. He was appointed by President George W. Bush to the Ocean Policy Commission and served during its full tenure from 2001 to 2004. He served in Japan, Vietnam, Spain, and Indonesia, and traveled extensively in official capacities.

He has been recognized with a number of military decorations; the Naval War College's J. William Middendorf Prize for Strategic Research, the Outstanding Public Service Award from the Virginia Research and Technology Consortium, and the Potomac Institute's Navigator Award. He has served on several boards of higher education and was a member of the Ocean Studies Board of the National Re-search Council from 2003 to 2005. He has been selected to be a public trustee for the New Jersey Consortium and chaired the Governor's Commission to Protect and Enhance New Jersey's Military Bases.

He graduated from the U.S. Naval Academy in 1968 and has a master's degree in mechanical engineering (ocean) from Catholic University and a master's of business administration from Jacksonville University.

Admiral Gaffney is currently the president of Monmouth University in West Long Branch, New Jersey.

**GENERAL PAUL J. KERN, USA (Ret.)**

*Former Commanding General, U.S. Army Materiel Command*

General Kern was commanding general, Army Materiel Command from 2001 to 2004, and senior adviser for Army Research, Development, and Acquisition from 1997 to 2001.

General Kern had three combat tours. Two were in Vietnam as a platoon leader and troop commander. His third was as commander of the Second Brigade of the 24th Infantry in Desert Shield/Desert Storm. The Second Brigade played a pivotal role in the historic attack on the Jalibah Airfield, which allowed the Twenty-Fourth Infantry Division to secure key objectives deep inside of Iraq. He also served as the assistant division commander of the division after its redeployment to Fort Stewart, Georgia.

General Kern's assignments included senior military assistant to Secretary of Defense William Perry. During that period, he accompanied Secretary Perry to more than 70 countries, meeting numerous heads of state, foreign ministers, and international defense leaders. He participated in U.S. operations in Haiti, Rwanda, Zaire, and the Balkans, and helped promote military relations in Central and Eastern Europe, South America, China, and the Middle East.

General Kern received the Defense and Army Distinguished Service Medals, Silver Star, Defense Superior Service Medal, Legion of Merit, two Bronze Star Medals for valor, three Bronze Star Medals for service in combat, and three Purple Hearts. He has been awarded the Society of Automotive Engineers Teeter Award, the Alumni Society Medal from the University of Michigan, and the German Cross of Honor of the Federal Armed Forces (Gold).

A native of West Orange, New Jersey, General Kern was commissioned as an armor lieutenant following graduation from West Point in 1967. He holds master's degrees in both civil and mechanical engineering from the University of Michigan, and he was a Senior Security Fellow at the John F. Kennedy School of Government at Harvard University.

He is an adviser to Battelle Memorial Institute and holds the Chair of the Class of 1950 for Advanced Technology at the United States Military Academy.

General Kern is a member of the Cohen Group, which provides strategic advice and guidance to corporate clients.

**ADMIRAL T. JOSEPH LOPEZ, USN (Ret.)**

*Former Commander-in-Chief, U.S. Naval Forces Europe and of Allied Forces, Southern Europe*

Admiral Lopez's naval career included tours as commander-in-chief of U.S. Naval Forces Europe and commander-in-chief, Allied Forces, Southern Europe from 1996 to 1998. He commanded all U.S. and Allied Bosnia Peace Keeping Forces in 1996; he served as deputy chief of naval operations for resources, warfare requirements and assessments in 1994 to 1996,; commander of the U.S. Sixth Fleet in 1992 to 1993; and senior military assistant to the secretary of defense in 1990 to 1992.

Admiral Lopez was awarded numerous medals and honors, including two Defense Distinguished Service Medals, two Navy Distinguished Service Medals, three Legion of Merits, the Bronze Star (Combat V), three Navy Commendation Medals (Combat V) and the Combat Action Ribbon. He is one of just two flag officers in the history of the U.S. Navy to achieve four-star rank after direct commission from enlisted service.

He holds a bachelor's degree (cum laude) in international relations and a master's degree in management. He has been awarded an honorary doctorate degree in humanities from West Virginia Institute of Technology and an honorary degree in information technology from Potomac State College of West Virginia University.

Admiral Lopez is president of Information Manufacturing Corporation (IMC), an information technology service integrator with major offices in Manassas, Virginia, and Rocket Center, West Virginia.

**ADMIRAL DONALD L. "DON" PILLING, USN (Ret.)**

*Former Vice Chief of Naval Operations*

Admiral Pilling assumed duties as the 30th vice chief of naval operations, the Navy's chief operating officer and second-ranking officer, from November 1997 until his retirement from active service in October 2000.

Ashore, he was assigned to a variety of defense resources and planning billets. In his earlier career, he served four years in program analysis and evaluation in the Office of the Secretary of Defense. As a more senior officer, he served as a Federal Executive Fellow at the Brookings Institution in 1985-86. A member of the National Security Council staff from 1989 until 1992, Admiral Pilling was selected to flag rank in 1989 while serving there. From 1993 to 1995, he was the director for programming on the staff of the Chief of Naval Operations, and later served as the Navy's chief financial officer from 1996 to 1997.

Admiral Pilling also commanded a warship; a destroyer squadron; a cruiser destroyer group; a carrier battle group; the U.S. Sixth Fleet; and NATO's Naval Striking and Support Forces Southern Europe.

Admiral Pilling has a bachelor's degree in engineering from the U.S. Naval Academy and a doctorate in mathematics from the University of Cambridge.

He served as vice president for strategic planning at Battelle Memorial Institute and became president and CEO of LMI, a nonprofit research organization, in 2002.

**ADMIRAL JOSEPH W. PRUEHER, USN (Ret.)**

*Former Commander-in-Chief of the U.S. Pacific Command (PACOM) and Former U.S. Ambassador to China*

Admiral Prueher completed thirty-five years in the United States Navy in 1999. His last command was commander-in-chief of the U.S. Pacific Command (CINCPAC); the largest military command in the world, spanning over half the earth's surface and including more than 300,000 people. Admiral Prueher also served as ambassador to China from 1999 to 2001. He served two presidents and was responsible for directing, coordinating, and managing the activities of all United States executive branch activities in China.

From 1989 through 1995, Admiral Prueher served as commandant at the U.S. Naval Academy at Annapolis; commander of Carrier Battle Group ONE based in San Diego; commander of the U.S. Mediterranean Sixth Fleet and of NATO Striking Forces based in Italy; and as vice chief of naval operations in the Pentagon.

Admiral Prueher graduated from Montgomery Bell Academy in Nashville, Tennessee, and then graduated with distinction in 1964 from the U.S. Naval Academy, later receiving a master's degree in international relations from George Washington University. He is also a graduate of the Naval War College in Newport, Rhode Island. In addition to co-authoring the Performance Testing manual used by naval test pilots for many years, he has published numerous articles on leadership, military readiness, and Pacific region security issues. Admiral Prueher has received multiple military awards for combat flying as well as naval and Joint Service. The governments of Singapore, Thailand, Japan, Korea, the Philippines, Indonesia, and Australia have decorated him.

Admiral Prueher is a consulting professor at Stanford University's Institute of International Studies and senior adviser on the Preventive Defense Project. He is on the board of trustees of the Nature Conservancy of Virginia.

**GENERAL GORDON R. SULLIVAN, USA (Ret.)**

*Chairman, Military Advisory Board*

*Former Chief of Staff, U.S. Army*

General Sullivan was the 32nd chief of staff—the senior general officer in the Army and a member of the Joint Chiefs of Staff. As the chief of staff of the Army, he created the vision and led the team that helped transition the Army from its Cold War posture.

His professional military education includes the U.S. Army Armor School Basic and Advanced Courses, the Command and General Staff College, and the Army War College. During his Army career, General Sullivan also served as vice chief of staff in 1990 to 1991; deputy chief of staff for operations and plans in 1989 to 1990; commanding general, First Infantry Division (Mechanized), Fort Riley, Kansas, in 1988 to 1989; deputy commandant, U.S. Army Command and General Staff College, Fort Leavenworth, Kansas, in 1987 to 1988; and assistant commandant, U.S. Army Armor School, Fort Knox, Kentucky, from 1983 to 1985. His overseas assignments included four tours in Europe, two in Vietnam and one in Korea. He served as chief of staff to Secretary of Defense Dick Cheney in the administration of President George H.W. Bush.

General Sullivan was commissioned a second lieutenant of armor and awarded a bachelor of arts degree in history from Norwich University in 1959. He holds a master's degree in political science from the University of New Hampshire.

General Sullivan is the president and chief operating officer of the Association of the United States Army, headquartered in Arlington, Virginia. He assumed his current position in 1998 after serving as president of Coleman Federal in Washington, D.C.

**VICE ADMIRAL RICHARD H. TRULY, USN (Ret.)**

*Former NASA Administrator, Shuttle Astronaut and the first Commander of the Naval Space Command*

Admiral Truly served as NASA's eighth administrator from 1989 to 1992, and his career in aviation and space programs of the U.S. Navy and NASA spanned 35 years. He retired as a vice admiral after a Navy career of more than thirty years. As a naval aviator, test pilot and astronaut, he logged over 7,500 hours and made over 300 carrier-arrested landings, day and night.

Admiral Truly was the first commander of Naval Space Command from 1983 to 1986 and became the first naval component commander of U.S. Space Command upon its formation in 1984. While still on active duty following the *Challenger* accident, he was called back to NASA as associate administrator for space flight in 1986 and led the accident investigation. He spearheaded the painstaking rebuilding of the space shuttle, including winning approval of President Reagan and the Congress for building of *Endeavor* to replace the lost *Challenger*. In 1989, President Reagan awarded him the Presidential Citizen's Medal.

Truly's astronaut career included work in the Air Force's Manned Orbiting Laboratory program, and NASA's Apollo, Skylab, Apollo-Soyuz and space shuttle programs. He piloted the *747/Enterprise* approach and landing tests in 1977, and lifted off in November 1981 as pilot aboard *Columbia*, the first shuttle to be reflown into space, establishing a world circular orbit altitude record. He commanded *Challenger* in August-September 1983, the first night launch/landing mission of the space shuttle program.

He served as vice president of the Georgia Institute of Technology and director of the Georgia Tech Research Institute (GTRI) from 1992 to 1997. Admiral Truly retired in January 2005 as director of the Department of Energy's National Renewable Energy Laboratory (NREL).

Truly is a member of the National Academy of Engineering. He has previously served on the board of visitors to the U.S. Naval Academy, the Defense Policy Board, the Army Science Board, and the Naval Studies Board. He is a member of the National Research Council Space Studies Board, a trustee of Regis University and the University Corporation for Atmospheric Research, and a member of the advisory committee to the Colorado School of Mines Board of Trustees.

**GENERAL CHARLES F. "CHUCK" WALD, USAF (Ret.)**

*Former Deputy Commander, Headquarters U.S. European Command (USEUCOM)*

From 2001 to 2002 General Wald was deputy chief of staff for air and space operations at the Pentagon, and from December 2002 until his retirement in 2006 General Wald was deputy commander, Headquarters U.S. European Command, Stuttgart, Germany. USEUCOM is responsible for all U.S. forces operating across 91 countries in Europe, Africa, Russia, parts of Asia and the Middle East, and most of the Atlantic Ocean.

General Wald commanded the 31st Fighter Wing at Aviano Air Base, Italy, where on Aug. 30, 1995, he led one of the wing's initial strike packages against the ammunition depot at Pale, Bosnia-Herzegovina, in one of the first NATO combat operations. General Wald commanded the Ninth Air Force and U.S. Central Command Air Forces, Shaw Air Force Base, South Carolina, where he led the development of the Afghanistan air campaign for Operation Enduring Freedom, including the idea of embedding tactical air control parties in ground special operations forces. He has combat time as an O-2A forward air controller in Vietnam and as an F-16 pilot flying over Bosnia. The general has served as a T-37 instructor pilot and F-15 flight commander. Other duties include chief of the U.S. Air Force Combat Terrorism Center, support group commander, operations group commander, and special assistant to the chief of staff for National Defense Review. He was also the director of strategic planning and policy at Headquarters U.S. Air Force, and served on the Joint Staff as the vice director for strategic plans and policy.

General Wald is a command pilot with more than 3,600 flying hours, including more than 430 combat hours over Vietnam, Cambodia, Laos, Iraq, and Bosnia. The general earned his commission through the Air Force ROTC program in 1971.

Currently, General Wald serves as president of Wald and Associates, an international management consulting and strategic planning firm, and is an adjunct lecturer at the Atlantic Council. He is also a member of the Bipartisan Policy Center, National Commission on Energy Policy, and the Securing America's Future Energy Commission.

**GENERAL ANTHONY C. "TONY" ZINNI, USMC (Ret.)**

*Former Commander-in-Chief of U.S. Central Command (CENTCOM)*

General Zinni's joint assignments included command of U.S. Central Command (CENTCOM), which is responsible for U.S. military assets and operations in the Middle East, Central Asia and East Africa.

General Zinni's joint assignments also include command of a joint task force and he has also had several joint and combined staff billets at task force and unified command levels. He has made deployments to the Mediterranean, the Caribbean, the Western Pacific, Northern Europe, and Korea. He has held numerous command and staff assignments that include platoon, company, battalion, regimental, Marine Expeditionary Unit, and Marine expeditionary force command. His staff assignments included service in operations, training, special operations, counter-terrorism and manpower billets. He has also been a tactics and operations instructor at several Marine Corps schools and was selected as a fellow on the Chief of Naval Operations Strategic Studies Group.

General Zinni joined the Marine Corps in 1961 and was commissioned an infantry second lieutenant in 1965. General Zinni holds a bachelor's degree in economics from Villanova University, a master's in international relations from Salvee Regina College, a master's in management and supervision from Central Michigan University, and honorary doctorates from William and Mary College and the Maine Maritime Academy.

He has worked with the University of California's Institute on Global Conflict and Cooperation, the U.S. Institute of Peace, and the Henry Dunant Centre for Humanitarian Dialogue in Geneva. He is on the International Council at the Joan B. Kroc Institute for Peace and Justice. He is also a Distinguished Advisor at the Center for Strategic and International Studies, a member of the Council on Foreign Relations. He has also been appointed as a member of the Virginia Commission on Military Bases.

General Zinni has co-authored, with Tom Clancy, a New York Times bestseller on his career entitled *Battle Ready*. His book, *The Battle For Peace: A Frontline Vision Of America's Power And Purpose*, was published in 2006.

# APPENDIX 2:
# CLIMATE CHANGE SCIENCE—A BRIEF OVERVIEW

There is a vast amount of scientific literature on the subject of climate change, and a complete discussion on the current state of the world climate and its deviation from climatological norms could fill volumes. In this appendix we discuss the consensus of the science community on climate change, effects observed thus far, and projections about what may happen in the future.

We have drawn information from the Intergovernmental Panel on Climate Change (IPCC), peer-reviewed scientific literature, and data, reports, and briefings from various respected sources, including the National Academy of Sciences, National Oceanic and Atmospheric Administration, National Air and Space Administration, and the United Kingdom's Hadley Centre for Climate Change

## CURRENT CONSENSUS

The IPCC's latest assessment report affirmed the following:

- While natural forces have influenced the earth's climate (and always will), human-induced changes in levels of atmospheric greenhouse gases are playing an increasingly dominant role.
- After considering the influences of the known causes of climate change—natural- and human-induced—the significant increase in the average global temperatures over the last half century can be attributed to human activities with a certainty of more than 90 percent [7].
- Those temperature increases have already affected various natural systems in many global regions.
- Future changes to the climate are inevitable.

## CHANGING GLOBAL TEMPERATURES

### INCREASED CARBON MEANS INCREASED TEMPERATURES

Throughout its history, the earth has experienced oscillations between warm and cool periods. These shifts in climate have been attributed to a variety of factors, known as "climate forcings," that include orbital variations, solar fluctuations, landmass distribution, volcanic activity, and the atmosphere's concentration of greenhouse gases, such as carbon dioxide, methane, and water vapor. The changes we see today are occurring at a more rapid rate than is explainable by known natural cycles [15].

Throughout the earth's past, temperature and greenhouse gas concentration have been closely linked through the planet's natural greenhouse effect; i.e. greenhouse gases trap heat in the atmosphere and thereby warm the earth. Throughout Earth's previous four glacial and warming cycles, atmospheric $CO_2$ concentration, and temperature show a high degree of correlation. Other greenhouse gases, such as methane, also show a similar relationship with temperature.

The recent and rapid rise in atmospheric $CO_2$ levels is of concern to climate scientists and policymakers. $CO_2$ concentrations never exceeded 300 parts per million by volume (ppmv) during previous large swings in climate conditions, but the $CO_2$ concentration now is about 380 ppmv [41], representing a 35 percent increase since the onset of the industrial revolution in the mid-eighteenth century. $CO_2$ levels are likely at their highest levels in the last 20 million years, and "the current rate of increase is unprecedented during at least the last 20,000 years" [41].

Thus, the current atmosphere is significantly different from its preindustrial state in a way that is compatible with increased heating.

### AVERAGE GLOBAL TEMPERATURES HAVE ALREADY BEGUN TO RISE

Average global surface temperature is the most fundamental measure of climate change, and there is no dispute that the earth's average temperature has been increasing over the last century (albeit not uniformly), with an acceleration in warming over the last 50 years. Over the last century, the average surface temperature around the world has increased by 1.3°F ± 0.3°F [7]. Temperatures since the 1950s were "likely the highest [of any 50-year period] in at least the past 1,300 years" [7]. Of the hottest twelve years on record since temperatures began to be measured in the 1850s, eleven have occurred in the last twelve years [7].

The burning of fossil fuels (such as oil, natural gas, and coal) is the main source of the rise in atmospheric $CO_2$ over the last two and a half centuries; deforestation and other changes in land use are responsible for a portion of the increase as well.

Human activities have also been responsible for a portion of the rise in other heat-trapping greenhouse gases, such as methane, which has risen 148 percent since preindustrial times, and nitrous oxide, which has risen 18 percent during the same period. Currently, half of the annual methane emitted is from activities such as burning fossil fuel and agricultural processes; [41] humans are responsible for about a third of nitrous oxide emissions, mainly from agriculture.

There is no known natural forcing that can account for the severity of the recent warming. For example, while claims are made that variation in the intensity of the sun is responsible, the variation in solar radiation's effect on the climate is estimated to be less than 5 percent as strong as that of human-induced greenhouse gases [7].

## MORE THAN TEMPERATURE RISE: OBSERVED IMPACTS ON EARTH'S NATURAL SYSTEMS

A 1.3°F increase in average global surface temperature over the last century may seem like an insignificant change, but in fact it has had a marked impact on many of the earth's natural systems.

### PRECIPITATION PATTERNS HAVE CHANGED

A change in the temperature of the atmosphere has a great impact on pre-cipitation patterns. As an air mass warms, it is able to hold more water vapor, so a warmer atmosphere can absorb more surface moisture and produce drier ground conditions. However, this increase in atmospheric content will also lead to more severe heavy rain events, when this higher water-content atmosphere drops its moisture.

Changes in precipitation amounts have been detected over large portions of the world. Annual precipitation has increased 5 to 10 percent over the past century across eastern North America, northern Europe, and northern and central Asia [7, 41]. The Mediterranean region experienced drying [7]. The tropics have witnessed a slightly lower increase, of 2 to 3 percent, and most of sub-Saharan Africa has shown a decrease in precipitation of 30 to 50 percent [42].

The Northern Hemisphere subtropics experienced a decrease in precipitation of approximately 2 percent [41]. Some of the most noticeable drying occurred in the Sahel and portions of southern Asia [7]. No significant change was detected in rainfall patterns across wide areas in the Southern Hemisphere; however, precipitation was noticeably decreased in southern Africa [41].

### EXTREME WEATHER EVENTS ARE MORE FREQUENT

Since 1950, cold days and nights and frost days have become less frequent, while hot days and nights and heat waves have become more frequent [7].

Global patterns of both heavy precipitation events and intense droughts have changed over recent decades. The increase in heavy precipitation events is consistent with the general increase in temperatures and the commensurate increase in atmospheric water vapor content. Droughts have become more intense, particularly in the tropics and subtropics, because of higher temperatures, more frequent heat waves, and changes in precipitation patterns [7].

The combination of increasing atmospheric temperatures and increased sea surface temperatures can increase the energy of tropical storms [43]. Preliminary observations since 1970 suggest that this effect has been observed in the North Atlantic and perhaps other regions as well [7].

### ICE AND SNOW COVER IS DISAPPEARING

Glacial ice and snow cover are disappearing in many regions around the world. The Arctic region, in particular, is one of the areas being affected most by rising temperatures. As a result of temperatures that have increased at nearly twice the global average rate, Arctic sea ice is thinning and shrinking in extent, glaciers are melting throughout the region, and the snow season has shortened. Alaskan glaciers have retreated at a rapid pace; in fact, the amount of glacial mass lost in Alaska alone represents half of the estimated worldwide total [44]. There will be little to no sea ice in the Arctic's summers toward the end of this century [7]. Glaciers in other regions, such as high-altitude glaciers in tropical areas, are also melting at an increasing rate [7].

Increased melting of the Greenland ice sheet is one of the most worrisome Earth responses observed thus far. Data from NASA's Goddard Space Flight Center show that the seasonal melt area over Greenland has trended upward at 7 percent per year over the last twenty-five years, and the ice shelf surrounding Greenland has thinned by 230 feet over the last five years [15]. Recent satellite data analyzed by NASA have shown that from 2003 through 2005, Greenland annually lost three times more ice through melting than it gained through snowfall [45].

Antarctica's ice cover has also responded to the increasing temperature, but in different ways. West Antarctica has lost ice mass, while the ice sheet in East Antarctica has thickened. The thickening has been explained as being due to increased snow fall (as a result of warming temperatures that lead to more water vapor in the atmosphere) [46] as well as a slowing of glaciers for reasons unrelated to climate [45].

The melting of ice cover is an important positive feedback that reinforces heating, because of ice's contribution to the reflectivity of the earth. As ice melts, it exposes either land or water, depending on its location. Because land and water both reflect less solar radiation than ice, they reinforce rising temperatures, which in turn melts more ice. Once such loops begin, predicting their stopping point is difficult.

### OCEANS ARE WARMING

The oceans have an enormous capacity to hold heat; because of their volume and heat capacity they require extremely large inputs of heat to change their temperatures. Nevertheless, the global mean sea surface temperature increased 0.9°F globally in the twentieth century [47], and the IPCC stated that "global ocean heat content has increased significantly since the late 1950s" [41].

### SEA LEVELS ARE RISING

Ocean temperature is important to sea level rise because as temperatures increase, water expands, causing sea levels to rise. Because of the thermal inertia of the oceans, once sea level begins to rise because of thermal ex-pansion, it will continue to do so for centuries regardless of any mitigative actions.

Sea levels are also raised by the melting of land-based ice and snow because of the direct transfer of water into the sea. Sea-based ice, however, does not raise sea levels as it melts.

From 1961 through 2003, global mean sea level has risen about three inches, with nearly half of that increase occurring between 1993 and 2003 [7]. Over the entirety of the twentieth century, sea levels have risen nearly seven inches. The IPCC concluded that this rise was caused by thermal expansion of the ocean as well as melting of mountain glaciers and snow cover [7].

OCEAN SALINITY HAS CHANGED

Oceanographers have observed dramatic changes in salinity levels in the oceans. Oceans in the mid- and high latitudes have shown evidence of freshening, while those in tropical regions have increased in salinity [7].

Increases in ocean acidity have also been observed since preindustrial times. Increased atmospheric $CO_2$ is absorbed in the ocean where it combines with water to form carbonic acid, a mild acid. Most people are familiar with acid rain; this is its ocean equivalent. Forecasts project the increase in acidity over the coming century to be three times as great as the increase over the last 250 years [7]. Higher acidity could have a major impact on ocean life by preventing the formation of shells and skeletons of some very numerous and important zooplankton [48]. Coral reefs are particularly vulnerable.

## FUTURE SCENARIOS: A CHOICE FOR HUMANS

To help illustrate the changes in climate that may occur, the IPCC developed a set of more than three dozen scenarios that describe different paths along which the world may evolve over the next century [49]. These paths are divided into six overarching categories distinguished by the assumptions made for factors such as economic growth, interactions among nations, population growth, and technological advances.

The scenarios were used as inputs to drive various climate models. The IPCC's 2007 report documents a range of climate change outcomes for the next century for each of the six categories used. According to the IPCC report, when considering the climate model results for each scenario, the average temperature projected in years 2090 to 2099 is expected to exceed the average temperature observed from 1980 to 1999 by 2.0° to 11.5°F. Sea levels are projected to rise between seven and twenty-three inches. This projection does not include the effect of potential changes in ice flow dynamics of large, land-based glaciers that may further contribute to the rise in sea level. To put this in perspective, recall that over the last century, the temperature increased about 1.3°F, and the sea level increased seven inches.

Because most of the inter-model studies assessed by the IPCC focus on three specific scenario categories, the IPCC's 2007 report necessarily focuses mostly on the same three. The "low" scenario (i.e., the one that results in the lowest temperature increase) describes a future in which population levels come under control, the global economy moves away from a manufacturing focus, and nations work together on improvements in environmental sustainability and developing clean technologies. The "medium" scenario describes a future where the assumptions regarding population and economic growth are similar to those made in the low scenario. Moreover, in the "medium" scenario the IPCC assumes the development of efficient technologies, and the production of energy from a variety of sources other than fossil fuels. The "high" scenario is the same as the "middle" scenario except energy production remains heavily focused on fossil fuel sources.

Each of the IPCC scenarios lead to different projections for temperature change; however, they all project significant global warming, with the most intense warming occurring in the Arctic and the high northern latitudes.

Some of the areas hardest hit by temperature increases will also very likely experience significantly less rainfall by the end of the century. Domestically, the southwestern portion of the United States will very likely experience the worst combination of these factors. Decreasing precipitation and markedly increasing temperatures will also stress northern and southern Africa and the Middle East.

While the earth's natural systems will continue to experience greater stress due to future climate changes, so will some key human systems [24]:

- **Coastal populations:** Increases in flooding and inundation from rising seas and more intense storms will affect coastal populations across the world, particularly those in Bangladesh and low-lying island nations.
- **Agriculture:** Temperature increases of a few degrees and increases in atmospheric $CO_2$ levels

may help agricultural productivity in mid- and high latitudes but will surely hurt agriculture in the tropics and subtropics, where crops already exist at the top of their temperature range; higher increases in temperature, as well as heat waves, changes in precipitation, and increased pests, will hurt agricultural productivity across much of the globe.

- **Water resources:** Five billion people are expected to live in water-stressed countries by 2025 even without factoring in climate change. Expected changes in climate will exacerbate water-stress in some areas (including most of Asia, southern Africa, and the Mediterranean), while alleviating it in others (such as the United Kingdom). Areas that depend on tropical mountain glaciers for water (such as Lima, Peru), will face a precarious situation as the glaciers continue to melt and eventually disappear. Developing nations with little capacity to manage water will be among the hardest hit.
- **Health:** Rising temperatures and heat waves will increase the number of heat-related deaths in summer months. This increase will be partially offset by decreases in cold-related winter deaths. The reach of vector-borne diseases, such as malaria and dengue fever, is expected to spread. Increasing frequency of floods will harm human health by its direct impact on populations as well as by facilitating the spread of disease to affected areas. Vital health infrastructure can be damaged, making minor and treatable injuries become life-threatening.

## A WILD CARD: ABRUPT CLIMATE CHANGE

For many years it was believed that climate changes have been gradual—that the earth gradually cycles between glacial periods and warm interglacial periods. We now know this is not always the case [50].

Abrupt climate changes present the most worrisome scenario for human societies because of the inherent difficulties in adapting to sudden changes. Abrupt sea level rise is particularly worrisome. The great ice sheets along the edges of Greenland and the West Antarctic are vulnerable to sudden breakup as the edges of the sheet thaw and meltwater seeps to the ice-ground boundary, the meltwater will act as a lubricant and facilitate a slippage into the sea. This physical phenomenon is an example of a positive feedback mechanism that, once started, is difficult to reverse [15]. Melting of these ice sheets would be catastrophic. The Greenland Ice Sheet could raise sea levels by twenty-three feet over a millennium [7]; the West Antarctic Ice Sheet would have a more immediate impact, raising sea levels more than three feet per century for five centuries [41]. The probability of a collapse of the West Antarctic Ice Sheet before 2100 is estimated to be between 5 and 10 percent [7].

None of these abrupt climate changes are projected by the climate models driven by the IPCC's 2007 future scenarios. However, if temperature increases were at the high end of the ranges projected by the models, abrupt climate changes such as those discussed above are more likely to occur. Such abrupt climate changes could make future adaptation extremely difficult, even for the most developed countries.

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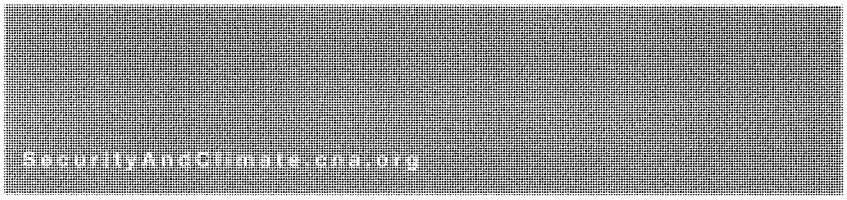


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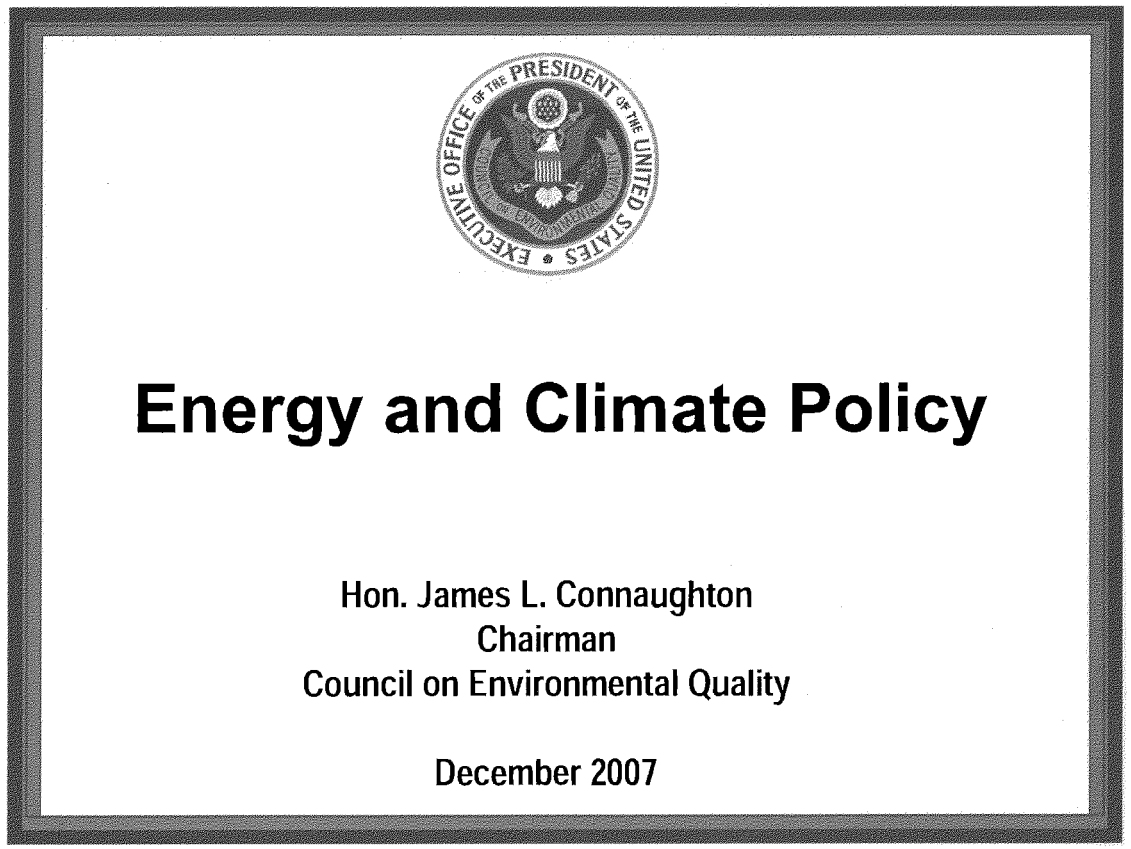



# Energy and Climate Policy

Hon. James L. Connaughton
Chairman
Council on Environmental Quality

December 2007

# Key Elements of Major Economies Discussions

- Long term global goal for greenhouse gas reduction, consistent with economic growth
- National plans that set mid-term goals
  - Use variety of binding and voluntary policies (mandates, incentives, partnerships)
  - Must be environmentally effective and measurable
- Collaborative technology development and deployment strategies for key sectors
  - Lower carbon fossil power generation, transportation, land use, and near zero carbon energy (e.g., efficiency, nuclear, wind, and solar)
  - International working groups on key sectors (to advance global and national efforts)
- Support adoption of existing clean technologies and the development of new ones
  - Elimination of tariffs and non-tariff barriers for clean energy goods and services
  - Enhanced financing tools
  - Expanded investment in global research and development
- Improved measurement and accounting systems that can more effectively track progress
- Robust programs on adaptation, forestry, and technology access for all countries

# U.S. National Initiatives Since 2001

*$37 Billion Federal Climate Budget*

*Bi-Partisan Support; More Than Any Other Country*

## Partnerships

- Nuclear Power 2010
- Improved NRC Process for Nuclear Power
- Climate Vision (15 Industry Sectors)
- Climate Leaders (100+ Company Leaders)
- Smartway Transportation Partnerships
- Energy Star and Natural Gas Star
- Federal Energy Management Programs

## Mandates

- Federal Fuel Economy ("CAFE")
  - 15% Increase in Light Trucks Through 2011
- Federal Renewable Fuels ("RFS")
  - 7.5 Billion Gallons By 2012
- Federal Appliance Efficiency
  - 40 Standards (15 From EPAct 2005)
- State Renewable Power ("RPS")
  - 24 States; 80% of Generation
  - Going from 5.6GW, now 14.6GW, to 32GW
- Building Codes- Federal Facilities & States
  - DOE Model Code 30% Improvement

## Incentives

- About $10 billion – EPAct 2005
- Clean Coal Investment Tax Credit ($1.6B + leveraging over $10B Private capital
- Loan Guarantees (power and fuels)
- Up to $3400 Tax Credit for Efficient Vehicles
- Up to $4000 in Home Solar Incentives
- Biological Sequestration part of $40+ Billion 2002 Farm Bill Conservation Programs

## Technology

- Renewable Power: Advanced Solar and Wind
- Nuclear Power: Generation IV and Fusion
- Coal: Low Carbon Research; Future Gen Zero Emissions Coal & Hydrogen Power Plant; Regional Carbon Capture & Storage Program
- Fuels: Cellulosic Ethanol, Bio-Diesel, Hydrogen
- Vehicles: Plug-in Hybrids, Hydrogen Fuel Cell
- Zero Energy Home Research

# Major New Initiatives This Year

## State of Union "Twenty in Ten"

- **Alternative Fuels Mandate**
  - Replace 15% projected annual gasoline use in 2017 with renewable and alternative fuels
  - Mandate use of 35B gallons of alternatives
  - Nearly 5 times 2012 target in current law
- **Vehicle Fuel Economy Mandate**
  - Displace 5% of projected annual gasoline use in 2017 with new mandatory rules
  - Produce up to 8.5 billion gallons in fuel savings over the next 10 years
  - New car standards; extend light truck rules
  - Specific targets should be set by experts at the National Highway and Traffic Safety Administration based on feasibility, safety, and benefit/cost assessment

## Executive Order

**Strengthening Federal Government Environmental, Energy and Transportation Management**

- Reduce Oil Consumption in Vehicles – 2%/year
- Increase Use of Renewable Fuels - 10%/year
- Improve energy efficiency – 30%/10 years
- Use More Renewable Power

## Farm Bill Conservation

- Portion of $50+B for Biological Sequestration
- $1.6B in New Funding for Energy Innovation
- $2B in Loans for Advanced Biofuel Plants

## 2008 Budget

- $2.7 B for the Advanced Energy Initiative
- Hydrogen Fuel
- Advanced Batteries for Plug-In Hybrid Vehicles
- Bio-Diesel
- New Ethanol Production Methods

# U.S. International Initiatives Since 2001

*More Cooperative, Faster, Real Results*

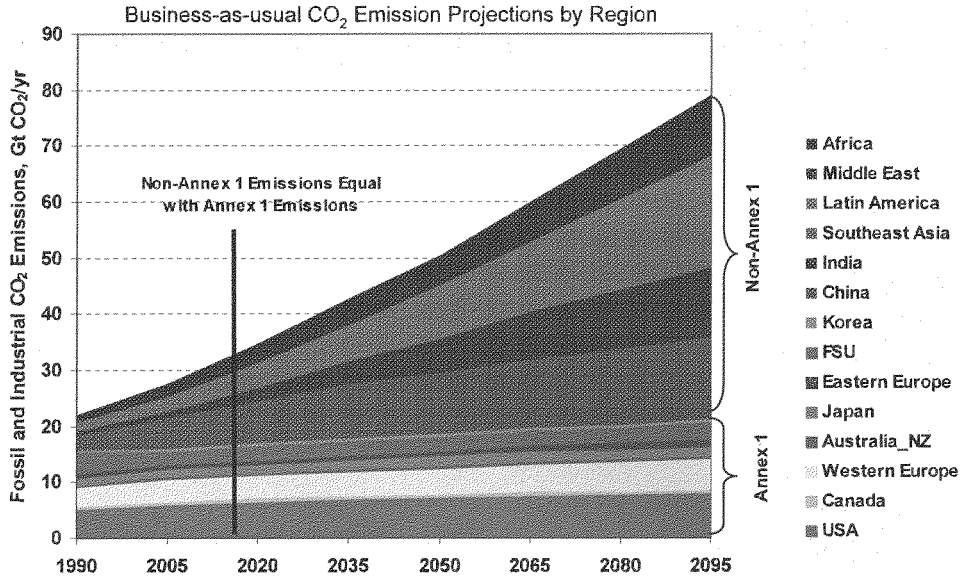
**Global Action Programs**

- Asia-Pacific Partnership (7 Nations)
  - Accounts for 50% of emissions
  - Nearly 100 actions
- G-8 Dialogue (13-20 Nations)
  - More than 40 programs
- Methane to Markets (20 Nations)
  - 180+ million tons reduced by 2015
- Renewable Energy and Efficiency (17 Nations)
- 12+ Bilateral Agreements on Technology and Lower Emissions
- Tropical Forest Conservation
- Stopping Illegal Logging

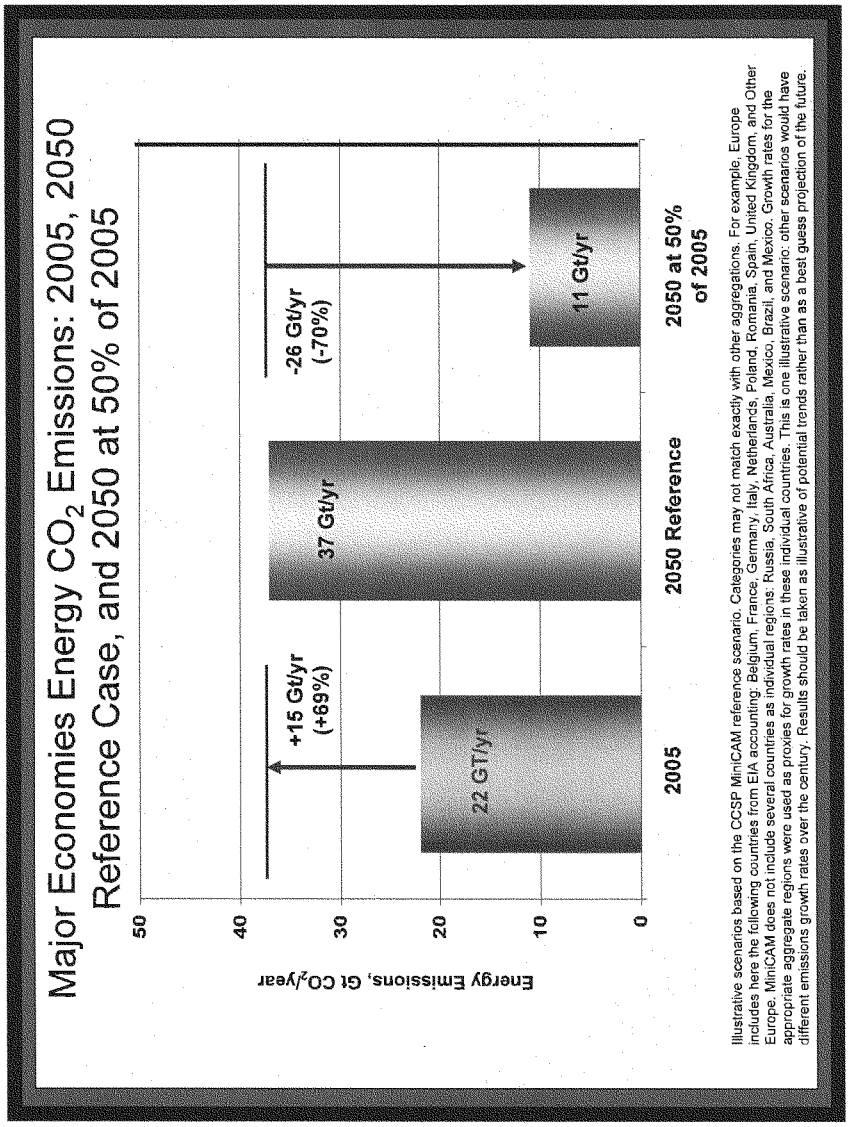
**Technology Advancement**

- Carbon Capture and Storage (22 Nations)
- Future Gen Coal (5 Nations)
- Hydrogen (17 Nations)
- Global Nuclear Energy Partnership (19 Nations)
- Gen IV Nuclear (10 Nations)
- Fusion Energy (7 Nations)
- Global Earth Observation (71 Nations)
  - Recommended by National Academy of Sciences

# Important Transitions in Emitting Countries Over the Coming Century



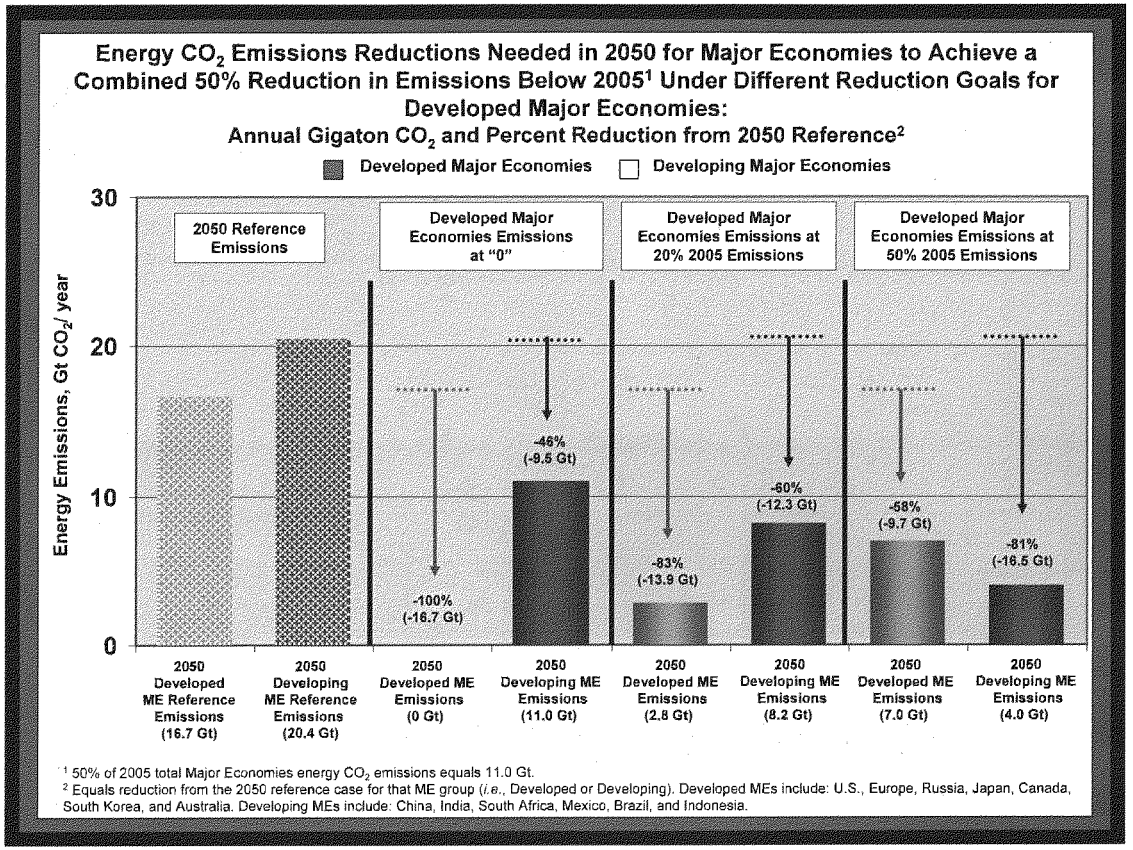

Data derived from *Global Energy Technology Strategy, Addressing Climate Change: Phase 2 Findings from an International Public-Private Sponsored Research Program*, Battelle Memorial Institute, 2007.


Major Economies Energy $CO_2$ Emissions: 2005, 2050 Reference Case, and 2050 at 50% of 2005
Energy Emissions, Gt $CO_2$/year
0
10
20
30
40
50
22 GT/yr
+15 Gt/yr (+69%)
37 Gt/yr
-26 Gt/yr (-70%)
11 Gt/yr
2005
2050 Reference
2050 at 50% of 2005
Illustrative scenarios based on the CCSP MiniCAM reference scenario. Categories may not match exactly with other aggregations. For example, Europe includes here the following countries from EIA accounting: Belgium, France, Germany, Italy, Netherlands, Poland, Romania, Spain, United Kingdom, and Other Europe. MiniCAM does not include several countries as individual regions: Russia, South Africa, Australia, Mexico, Brazil, and Mexico. Growth rates for the appropriate aggregate regions were used as proxies for growth rates in these individual countries. This is one illustrative scenario: other scenarios would have different emissions growth rates over the century. Results should be taken as illustrative of potential trends rather than as a best guess projection of the future.

# How Big is One Gigaton of $CO_2$?

| Technology | Actions that Provide One Gigaton $CO_2$/ Year of Mitigation or Offsets |
|---|---|
| Coal-Fired Power Plants | Build 273 "zero-emission" 500 MW coal-fired power plants*<br>*Equivalent to about 7% of estimated current global installed coal-fired generating capacity of 2 million MW* |
| Geologic Sequestration | Install 1,000 sequestration sites like Norway's Sleipner project (1 $MtCO_2$/year)<br>*Only 3 sequestration projects of this scale exist today* |
| Nuclear | Build 136 new nuclear power plants of 1 GW each instead of new coal-fired power plants without CCS<br>*Equivalent to about one third of existing worldwide nuclear capacity of 375 GW* |
| Efficiency | Deploy 273 million new cars at 40 miles per gallon (mpg) instead of 20 mpg - or at 14 km/L instead of 7 km/L |
| Wind Energy | Install capacity to produce ~4 times global wind generation of about 74 GW<br>*Equivalent to about 270,000 1 MW wind turbines* |
| Solar Photovoltaics | Install about 750 GW of solar PV, which is 125 times current global installed capacity of 6 GW |
| Biofuels | Using existing production technologies, convert a barren area about 2 times the size of the UK (for a total of over 480,000 $km^2$) |
| $CO_2$ Storage in New Forest | Convert a barren area greater than the size of Germany and France together (for a total of over 900,000 $km^2$) |

Gigatons = $10^9$ Metric tons (1000 Kilograms)
*Instead of coal-fired power plants
*Source*: Climate Change Technology Program *Strategic Plan*, September 2006.


Energy $CO_2$ Emissions Reductions Needed in 2050 for Major Economies to Achieve a Combined 50% Reduction in Emissions Below 2005[1] Under Different Reduction Goals for Developed Major Economies:
Annual Gigaton $CO_2$ and Percent Reduction from 2050 Reference[2]
Developed Major Economies
Developing Major Economies
Energy Emissions, Gt $CO_2$/ year
30
20
10
0
2050 Reference Emissions
Developed Major Economies Emissions at "0"
Developed Major Economies Emissions at 20% 2005 Emissions
Developed Major Economies Emissions at 50% 2005 Emissions
-100% (-16.7 Gt)
-46% (-9.5 Gt)
-83% (-13.9 Gt)
-60% (-12.3 Gt)
-58% (-9.7 Gt)
-81% (-16.5 Gt)
2050 Developed ME Reference Emissions (16.7 Gt)
2050 Developing ME Reference Emissions (20.4 Gt)
2050 Developed ME Emissions (0 Gt)
2050 Developing ME Emissions (11.0 Gt)
2050 Developed ME Emissions (2.8 Gt)
2050 Developing ME Emissions (8.2 Gt)
2050 Developed ME Emissions (7.0 Gt)
2050 Developing ME Emissions (4.0 Gt)
[1] 50% of 2005 total Major Economies energy $CO_2$ emissions equals 11.0 Gt.
[2] Equals reduction from the 2050 reference case for that ME group (i.e., Developed or Developing). Developed MEs include: U.S., Europe, Russia, Japan, Canada, South Korea, and Australia. Developing MEs include: China, India, South Africa, Mexico, Brazil, and Indonesia.

ONE HUNDRED ELEVENTH CONGRESS

# Congress of the United States

## House of Representatives

COMMITTEE ON ENERGY AND COMMERCE
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March 24, 2009

Mr. R James Woolsey
Senior Executive Advisor
Booz Allen Hamilton
8283 Greensboro Drive
McLean, Virginia 22102

Dear Mr. Woolsey:

Thank you for appearing before the Subcommittee on Energy and Environment on February 12, 2009, at the hearing entitled "The Climate Crisis: National Security, Public Health, and Economic Threats".

Pursuant to the Committee's Rules, attached are written questions for the record directed to you from certain Members of the Committee. In preparing your answers, please address your response to the Member who submitted the questions and include the text of the question with your response, using separate pages for responses to each Member.

Please provide your responses by April 7, 2009, to Earley Green, Chief Clerk, in Room 2125 of the Rayburn House Office Building and via e-mail to Earley.Green@mail.house.gov. Please contact Earley Green or Jennifer Berenholz at (202) 225-2927 if you have any questions.

Sincerely,

Henry A. Waxman
Chairman

Attachment

**The Honorable Gene Green**

1. You made several observations in your work on "malevolent and malignant threats" regarding climate change's impacts on our energy infrastructure.

   Can you further elaborate on your point that our energy systems our vulnerable to climate change?

**The Honorable Joe Barton and the Honorable Fred Upton**

1. When it comes to energy security, you suggest that we must reduce our dependence on oil.

    a. If the United States reduced its oil demand, the first barrel of oil withheld from production would likely come from the highest marginal cost production. That means first we would withhold from Canada, then probably our own domestic production, while the Middle East would continue to supply us. Have you assessed this situation? What is the strategic value from harming our allies or own production before we have an impact on the Middle East?

    b. On a related note: Even if the United States drastically cut its oil use, the developing world will continue to demand oil – continuing to enrich the Middle East and other unsavory suppliers of cheap oil. Al-Qaeda would still be able to receive its tens of millions in support money. How will this affect our security?

2. When you were the Director of Central Intelligence from 1993-1995 you were presumably tasked with establishing a budget for many of the intelligence agencies. Where did climate change fall as a priority within your budget?

    a. Where would you place it as a priority now?
    b. What types of other threats would you consider a higher priority?
    c. What types of other threats would you consider a lower priority?

3. What is the impact on national security if all energy intensive industries moved overseas? What would be the national security impact if we lost more of our manufacturing base?

House Committee on Energy and Commerce

Answers to Questions Submitted After Hearings of February 12, 2009

Witness: R. James Woolsey

Congressman Green

Q 1.

My discussion of "malignant" and "malevolent" threats regarding energy is generally not about climate change's impact on our energy infrastructure - although there may well be some -- but rather about how these two types of threats to us derive in part from the way we have built, fueled, and used our energy systems.

"Malignant" threats, as I use the term, are threats that are unintentionally created because we depend on complex systems that can fail in chaotic and sometimes unpredictable ways due to seemingly small disturbances in them. Examples would be the large-scale grid failures in: (1) 2003 (in Ohio, the Northeastern US, and Eastern Canada) of our overstretched electricity grid due to a power line touching a tree branch in Cleveland, and (2) 2008 (in Florida) due to, essentially, a short in a single bottle switch in a substation in Miami. Other "malignant" effects would be potential positive feed-back loops (escalating exponential failures) in the West Antarctic and Greenland ice sheets due in part to carbon dioxide put into the atmosphere by the burning of fossil fuels in our energy systems.

Insofar as increased incidents of extreme weather in turn cause malfunctions of energy systems, these could be said to be "malignant" as well. One example would be the shut-down of a number of nuclear power plants in France early in this decade - and the deaths of thousands of the elderly from heat as air conditioning and fans failed -- due to water problems during an extremely hot summer.

"Malevolent" threats, in this terminology, would on the other hand be conscious decisions by others to increase our insecurity, decisions caused or made possible in part by the way we design, operate and fuel our energy systems. Examples

would be possible Chinese or Russian cyber-attacks on the vulnerable control systems for our electric grid, or the fact that the world's almost complete dependence on oil for transportation has provided to Iran the funds it now uses in its nuclear weapons program.

Congressmen Barton and Upton

Q 1 a

When one begins to rely less on a commodity in favor of a substitute there is no way to avoid the higher-cost suppliers losing business before the lower-cost ones. But the conclusion I draw from that fact is not that we should relax and accept our oil dependence but rather that we must move as rapidly as possible to destroy oil's monopoly (some 96 per cent) over transportation so that we may break OPEC's power as quickly as possible. I believe we can do this relatively quickly if we orient all relevant national policies to moving rapidly both to electrify much of transportation (e.g. with plug-in hybrids) and simultaneously to move toward second-generation biofuels such as those with cellulosic and waste feedstocks.

Q1b

There is no reason for us to try to maintain wholly within our own borders the technologies, such as battery and biofuel developments, that will help others as well as ourselves move away from oil dependence. We need to maintain manufacturing capabilities but they need not be exclusive. This is an issue, in my view, where our interests are quite compatible with those of other oil importers such as India and China. They would be well-advised to move away from oil as well.

2 a, b, and c

Intelligence is generally, in my view, about stealing secrets from enemies and potential enemies and analyzing that information, together with other

information from open sources, to help the President and other decisionmakers in their responsibilities. As such, climate change is not a traditional intelligence target - it wasn't in 1993-95 and it isn't now. Judgments about the likelihood and nature of climate change should, I believe, principally be the responsibility of a part of the government with appropriate expertise, e.g. NOAA.

Where those judgments could affect the planning of a government agency, then that agency should take the material provided by, say, NOAA and consider changing its planning accordingly - e.g., I think it is plausible to believe that increasingly unpredictable climate events may lead to a greater need to use our military forces for humanitarian missions such as the aid we provided to Indonesia several years ago following the tsunami there.

In my view the two principal questions on which intelligence intersects with climate change are: 1) How might climatic instability and temperature changes in some parts of the world affect the behavior of states due to water and food shortages, migration, social instability, and the like? and 2) How can the intelligence community most effectively continue to provide information to the rest of the government - e g from reconnaissance satellites and other sensors - of phenomena such as glacier, ice-sheet, and oceanographic changes.

Only the last point was a salient one in 1993-95 since the program to provide to climate scientists reconnaissance satellite information about various environmental matters had begun several years earlier. I helped expand that cooperation but the cost to the intelligence community was negligible since the digital reconnaissance data had been stored for some years as part of the natural operation of the satellites.

I don't believe these priorities or proper roles for intelligence have changed substantially over the years. The only possible difference is that climate change may now appear to affect the potential behavior of some nations sooner than would have been thought a decade and a half ago. Whatever the formal priority of climate change work in the intelligence community it would be as short-

sighted to neglect to assess its potential affect as to neglect demography, another determinant of human behavior that it is important to assess even though the US Government needs to steal no secrets in order to consider its potential effects. There is some chance, for example, if one considers possible developments in both climate change and demography, that by the middle of the century Russia may have a population smaller than Yemen (under 100 million), over one-third of it Muslim, and be seeing increased attempted immigration by large numbers of Chinese fleeing flooded coasts into a somewhat warmer Siberia. These trends may not play out in this way, but it would not be responsible for the intelligence community to ignore such possibilities in assessing potential developments in Russian and Chinese behavior in coming years.

Q3

There would obviously be a very negative effect on the US if all energy-intensive industries moved overseas and doubtless a negative effect in losing manufacturing base. But I would point out that methods of counteracting such effects are available to the Executive and the Congress. For example, in the 1980's the US became concerned about our loss of computer chip manufacturing capacity to Asia and the Congress established Sematech, a public-private partnership to permit American chip manufacturers to cooperate and improve their technology and manufacturing capability. It was quite successful. I would think that one way to deal with the negative effects of our oil dependence would be, e.g., to establish a Sematech for batteries to help us hasten the day when we can electrify an important share of transportation with American-produced energy systems.

I would not favor accepting oil's monopoly of transportation and OPEC's near-monopoly of oil as the favored path. In my view if one does not want to move away from oil dependence because of climate-change concerns, that is fine - the fact that we are currently funding both sides of the war against Islamist terrorism should be sufficient reason in and of itself to undertake such an effort.

Questions for Dr. Kristie L. Ebi

**The Honorable Gene Green:**

1. ***Can you explain how increasing temperatures could facilitate the development of ground level ozone and how this could impact public health within pollution-prone areas?***

Air pollution concentrations are the result of interactions among local weather patterns, atmospheric circulation features, wind, topography, human activities (i.e. transport and coal-fired electricity generation), human responses to weather changes (i.e. the onset of cold or warm spells may increase heating and cooling needs, and therefore energy needs), and other factors. Some locations, because of their general climate and topographical setting, are predisposed to poor air quality because the climate is conducive to chemical reactions leading to the transformation of emissions, and the topography restricts the dispersion of pollutants.

Ground-level ozone is both naturally occurring and, as the primary constituent of urban smog, a secondary pollutant formed through photochemical reactions involving nitrogen oxides and volatile organic compounds in the presence of bright sunshine with high temperatures. Land use changes over the past century affect ozone concentrations by altering vegetation patterns that affect biogenic volatile organic compound emissions that influence ozone production. In addition, urbanization leading to heat islands can influence the local production and dispersion of ozone. In urban areas, gasoline-burning engines are major sources of volatile organic compounds, and nitrogen oxides are produced whenever fossil fuels are burned. Temperature, wind, solar radiation, atmospheric moisture, venting and mixing affects both emissions of ozone precursors and production of ozone. Because ozone formation depends on sunlight, concentrations are typically highest during the summer months, although not all cities have shown seasonality in ozone concentrations.

There are two major sources of uncertainty when assessing the health impacts of future changes in tropospheric ozone concentrations: the extent of future changes in emissions of ozone precursors; and the degree to which future weather conditions could increase ozone concentrations. Future emissions are, of course, uncertain and depend on assumptions of population growth, economic development, regulatory actions, and energy use. Increased regulation of anthropogenic emissions of volatile organic compounds and nitrogen oxides from gasoline powered engines means that biomass burning, including fires, will likely increase in importance as sources of ozone precursors. Assuming no change in the emissions of ozone precursors, the extent to which climate change affects the frequency of future "ozone episodes" will depend on the occurrence of the required meteorological conditions. Where climate change is projected to result in an increased frequency of stable anticyclonic conditions with little boundary layer ventilation and associated high temperatures, cloud free conditions, and large solar radiation inputs, it may be expected that exceedance of current air quality standards will likely occur.

Ground-level ozone is a known pulmonary irritant that affects the respiratory mucous membranes, other lung tissues, and respiratory function.

Exposure to elevated concentrations of ozone is associated with increased hospital admissions for pneumonia, chronic obstructive pulmonary disease, asthma, allergic rhinitis, and other respiratory diseases, and with premature mortality. Table 1 summarizes recent studies of the health consequences of changes in ozone concentrations due to climate change; all project at least a small increase in mortality in a warmer world.

Reference: Ebi KL, McGregor G. Climate change, tropospheric ozone and particulate matter, and health impacts. Environmental Health Perspectives 2008;116:1449-1455; doi:10.1289/ehp.11463

**Table 1: Projected impacts of climate change on ozone-related health effects**

| Area | Health effect | Model | Climate scenario<br>Time slices | Temperature increase and baseline | Population projections and other assumptions | Main results | Reference |
|---|---|---|---|---|---|---|---|
| New York metropolitan region, U.S. | Ozone-related deaths by county | Concentration response function from published epidemiologic literature. Gridded ozone concentrations from CMAQ (Community Multiscale Air Quality model). | GISS driven by SRES A2, downscaled using MM5.<br>2050s | 1.6 to 3.2°C in 2050s compared with 1990s | Population and age structure held constant at year 2000. Assumes no change from U.S. EPA 1996 national emissions inventory and A2; consistent increases in $NO_x$ and VOCs by 2050s. | A2 climate only: 4.5% increase in ozone-related deaths. Ozone elevated in all counties.<br>A2 climate and precursors: 4.4% increase in ozone-related-deaths. (Ozone not elevated in all areas due to $NO_x$ interactions) | (Knowlton et al. 2004) |
| 50 cities, eastern U.S. | Ozone-related hospitalizations and deaths | Concentration response function from published epidemiologic literature. Gridded ozone concentrations from CMAQ. | GISS driven by SRES A2, downscaled using MM5.<br>2050s | 1.6 to 3.2°C in 2050s compared with 1990s | Population and age structure held constant at year 2000. Assumes no change from U.S. EPA 1996 national emissions inventory and A2-consistent | Maximum ozone concentrations increase for all cities, with the largest increases in cities with currently higher concentrations. 68% increase in average number of days/summer exceeding the 8- | (Bell et al. 2007) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | increases in $NO_x$ and VOCs by 2050s. | hour regulatory standard, resulting in 0.11to 0.27% increase in non-accidental mortality and an average 0.31% increase in cardiovascular disease mortality. | |
| Los Angeles and San Diego regions, California, U.S. | Ozone-related hospitalizations and deaths | Concentration response function from published epidemiologic literature. Gridded ozone concentrations. | HadCM3 driven by SRES A2, downscaled using MM5, then a photochemical model (CAMx) in the 2050s and 2090s. | 2.1 to 2.7°C in 2050s, and 4.6 to 5.5°C in 2090s | Population and age structure held constant. Assumes no change from U.S. EPA 1997 national emissions inventory and A2-consistent increases in $NO_x$ and VOCs by 2050s and 2090s. | Average increase in ozone peaks of 2.0 to 3.2 ppb in the 2050s, and 3.1 to 4.8 ppb in the 2090s. Increases in maximum peak concentrations are 2 to 3-fold higher. Percent increase in daily mortality in the 2050s range from 0.08 to 0.46 depending on the exposure-response relationship. Increases in the 2090s are 0.12 to 0.69. Projected increases in hospital admissions are higher. | (Hwang et al. 2004) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| England and Wales, U.K. | Exceedance days (ozone, particulates, $NO_x$) | Statistical, based on meteorological factors for high pollutant days (temperature, wind speed); Projections of U.K. and northwest Europe urban traffic emissions of ozone precursors | UKCIP scenarios 2020s, 2050s, 2080s | 0.57 to 1.38°C in 2020s; 0.89 to 2.44°C in 2050s; 1.13 to 3.47°C in 2080s compared with 1961to 1990 baseline | Population and age structure held constant | Over all time periods, large decreases in days with high particulates and $SO_2$, small decrease in other pollutants except ozone, which increases. If a threshold is assumed, then the increase in health effects due to ozone would be relatively small. If no threshold is assumed, then ozone is projected to increase premature deaths by 10%, 20%, and 40% for the years 2020, 2050, and 2080, respectively. | (Anderson et al. 2001) |
| Ten world regions | Premature mortality from acute ozone exposure | Ozone-mortality coefficient from a study of 95 cities in the US. | Coupled general circulation model with interactive chemistry (LMDz-INCA) driven by SRES | Baseline simulated for 2000 | Population growth and emissions under SRES A2. One realization included recently | Large increase in ozone in 2030 under the A2 scenario; global population-weighted 8-hour ozone increased 9.4 ppbv. Along | (West et al. 2007) |

| | | | |
|---|---|---|---|
| | A2 for 2030 | enacted legislative to control ozone, and another assumed maximum feasible reduction of ozone precursors | with population growth, this was associated with approximately 500,000 additional deaths.<br>Using a threshold of 25 ppbv, 191,000 deaths worldwide could be avoided using currently enacted legislation, and 458,000 deaths could be avoided using maximum feasible reduction technologies. |

2. ***How specifically do you suggest the U.S. coordinate all public health responses to climate change across the federal government?***

Effectively addressing the health risks of climate variability and change will require wide-ranging responses from Federal and State agencies and departments. Because the health risks of and public health responses to climate change cover a broad range of issues, and because the risk and responses will change over temporal and spatial scales, there should be Federal coordination of programs and activities, within the CCSP or a similar organization, to ensure that funding focuses on critical research needs to address current gaps and those likely to arise within the next few decades. Programs and activities designed to address climate change and health issues should be established within all Federal agencies whose mission mandate includes human health, including Departments of Commerce (specifically the National Oceanographic and Atmospheric Administration), Health and Human Services (particularly the Centers for Disease Control and Prevention), Homeland Security, Environmental Protection Agency, the National Institutes of Health, National Science Foundation, and the U.S. Geological Survey.

A robust research strategy to address the health risks of climate change, including the health aspects of climate mitigation and adaptation policies, should integrate four broad research activities: characterizing associations between weather/climate and health based on observed data; identifying observed effects of climate change on health; projecting health impacts using models; and identifying, prioritizing, evaluating, implementing, and monitoring effective and timely response options (including adaptation and mitigation). Key public health research categories that address these essential services include surveillance and monitoring; field, laboratory, and epidemiologic research; model development; development of decision support tools; and education and capacity building of the public and public health and health care professionals.

Ensuring that a Federal research program prepares the U.S. for the current and projected health impacts of climate change would be facilitated by establishing a standing committee within the National Academy of Sciences to advise on the size, priorities, and balance of such a program, through independent and regular evaluations of the state of knowledge and critical research gaps to address current and projected health risks.

Reference: Ebi KL, Balbus J, Kinney PL, Lipp E, Mills D, O'Neill MS, Wilson M. 2009. U.S. funding is insufficient to address the human health impacts of and public health responses to climate variability and change. Environmental Health Perspectives (in press).

**The Honorable Lois Capps:**

1. ***The World Health Organization estimates that 150,000 people die every year due to causes related to global warming. Like many congressional districts in California, my district suffers from poor air quality. I'm very concerned about the effect this pollution has on my constituents, particularly the young, the elderly, and those already suffering from respiratory illnesses like asthma. To what extent is global warming contributing to the detrimental health impacts cause by air pollution and how are those impacts likely to increase in the coming decades?***

Dr. McGregor and I recently reviewed studies projecting the impacts of climate change on air quality and studies projecting the impacts of these changes on morbidity and mortality (Ebi and McGregor 2008). Our conclusions include the following.

Poor air quality currently affects the health of millions of people. Climate change has the potential to increase harmful exposures to elevated concentrations of ozone and PM2.5 through changes in regional weather patterns. However, there is high uncertainty about future projections; sources of uncertainty include not only future climate change, but also future emissions of greenhouse gases, ozone precursors, and other pollutants, as well as how population vulnerability and activity patterns may differ in the future.

Because of the high uncertainty of the extent and effectiveness of future emissions reductions, most studies that projected the impacts of climate change on air quality focused on future climate change alone and held precursor emissions constant over future decades. Therefore, the focus was on examining the sensitivity of ozone concentrations to alternative future climates rather than on attempting to project actual future ozone concentrations. Based on a limited number of modeling studies, climate change is likely to increase ozone concentrations in high-income countries when precursor emissions are held constant, leading to increased morbidity and mortality. There is less certainty of the possible impact of climate change on fine particulate concentrations.

Projections of future mortality due to increased ozone concentrations due to increased ambient temperature are summarized in Table 1.

Ebi KL, McGregor G. Climate change, tropospheric ozone and particulate matter, and health impacts. Environmental Health Perspectives 2008;116:1449-1455; doi:10.1289/ehp.11463

2. ***The health risks that can be attribute to global warming are broad in scope – from air pollution; to severe weather events like floods, droughts, heat waves, and hurricanes; to the shifting range of disease-carrying vectors. The U.S. needs to be a leader moving forward, both in mitigating climate change and adapting to it. I've introduced legislation to help coastal states plan and prepare for some of the expected impacts of global warming, such as sea level rise. Do you think we should be doing the same kind of planning and preparation to manage the projected health risks of climate change?***

Yes. Synthesis and Assessment Product 4.6 (Analyses and Effects of Global

Change on Human Health and Welfare and Human Systems) concluded that climate change poses real health risks for U.S. populations. Although the U.S. has a well-developed public health infrastructure and environmental regulatory program to protect our air and water, climate change is projected to challenge the ability of these programs to achieve their stated goals. Addressing the projected health risks of climate change is a pressing challenge for public health. An effective public health response to climate change is essential to preventing injuries and illnesses, enhancing public health preparedness, and reducing risk. Although the scope and complexity of the challenge are unprecedented, there is a conceptual framework for responding that draws on long-standing public health thinking, the Essential Services of Public Health (Frumkin et al. 2008).

Reference: Frumkin H, Hess J, Luber G, Malilay J, McGeehin M. 2008. Climate change: the public heath response. Am J Public Health 98:435-445.

**The Honorable Joe Barton and the Honorable Fred Upton:**

1. ***There is little dispute a rise in global temperatures may increase the prevalence of mosquitoes in areas where they previously may not have been a problem. Worse, these mosquitoes, especially in developing countries, may carry malaria. What, in your opinion, is the most effective way of dealing with the malaria virus? Does a cap on carbon emissions meet the criteria of a cost-effective solution to this problem?***

Malaria is caused by four species of the protozoan parasite *Plasmodium*. Malaria has proved a complex and difficult disease to control, in part because of the ability of the *Plasmodium* to quickly adapt to changing environmental conditions and control methods. Current methods of malaria control include use of insecticide treated bednets, indoor residual spraying, pharmacology, integrated vector management, alteration of habitats, and, in some areas, perimeter spraying. Despite known control methods, malaria continues to kill 1-3 million children annually.

CO2 is not destroyed chemically; its removal from the atmosphere occurs through multiple processes that store the carbon transiently in land and ocean reservoirs and ultimately in mineral deposits. Natural processes currently remove about half the incremental anthropogenic CO2 added to the atmosphere annually; the balance is removed over 100 to 200 years. This inherent inertia in the climate system means that the earth is committed to decades of climate change from the greenhouse gases currently in the atmosphere. Actions taken in the next 10 to 20 years will have only a limited effect on the climate over the next 40 to 50 years, but investing in mitigation now may avoid some of the severe consequences projected for later in the century. The longer serious reductions in greenhouse gas emissions are delayed, the higher will be the projected costs for both mitigation and adaptation.

Therefore, a cap on carbon emissions should be an effective approach to reducing future risks of climate change-related alterations in the geographic range and incidence of malaria. However, focusing only on capping emissions would not prevent climate change-related malaria deaths occurring today and over the next several decades.

2. ***Projections of world economic growth show that the developing world will be wealthier 100 years from now. How have you accounted for this in your assessments?***

Projections of future health burdens attributed to climate change often are based on one or more of the Standardized Reference Emission Scenarios (SRES), which incorporate socioeconomic development. Projected future GDP is quite uncertain because it depends on (1) the assumed rate of population growth, (2) specific economic assumptions made about growth and the implementation of technological changes, (3) the characteristics of the economic model used to project GDP, and (4) assumptions about future exchange rates. Downscaling adds further uncertainty. All of the SRES storylines describe futures that are more affluent than today, with gross world product rising 10- to 26-fold. Along with the increasing

income is a narrowing of income differences among world regions; this implies very high growth rates for all currently developing countries – even those, particularly in Africa, that have shown negative to little growth over the past few decades.

3. ***The U.S. emits about 5.5 billion tons of energy-based CO2 each year. The developing world today produces about 14 billion tons. By 2030, the U.S. and Western Europe, Canada, other developed countries will add about 2 billion tons annually by official estimates. The developing world – China, India, the Middle East, and Africa – will produce another 12.8 billion tons of energy-based CO2 over this time. How will the United States cutting its emissions affect global warming and public health if the developing world does not cut its emissions to half of today's emissions? Have you estimated the cost of that action?***

The climate change attributable public health and other impacts being observed today, and the impacts that will likely be observed over the next few decades, are primarily a consequence of greenhouse gas emissions from the United States, Europe, Japan, and other developed countries. This historic responsibility for atmospheric greenhouse gases and the resulting impacts are recognized within the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC also recognizes that these countries need to demonstrate leadership in reducing their emissions, under the principle of differentiated responsibilities:

> *Each non-Annex I Party shall, in accordance with Article 12, paragraph 1 (b), communicate to the Conference of the Parties a general description of steps taken or envisaged by the Party to implement the Convention, taking into account its common but differentiated responsibilities and specific national and regional development priorities, objectives and circumstances.*

The costs of action and inaction to reduce greenhouse gas emissions by various countries and regions often are estimated by integrated assessment modeling experiments. Unfortunately, there is no model of the health risks of climate change that could be linked with integrated assessment models to estimate these costs. Models are needed to estimate the costs of action and inaction on the public health risks of climate change because climate is one of multiple factors that influence the incidence and range of many health determinants and outcomes.

Health models that can explore the range of potential impacts of a changing climate in the context of other drivers of population health are critical to better understand where, when, in what population group(s), and with what intensity climate variability and change could have negative health consequences. Identification of vulnerable populations and locations can be used by risk managers to facilitate the development and implementation of effective and efficient adaptation policies and measures to reduce projected negative impacts, and can be used by policymakers to identify mitigation targets and the possible health consequences of approaches to meet those targets. Policymakers also can use model results to "climate-proof" decisions, to better ensure that the interventions implemented will be resilient to changing weather patterns and trends.

Reference: Ebi KL. Healthy people 2100: modeling population health impacts of climate change. Climatic Change 2008:88:5-19; doi: 10.1007/s10584-006-9233-0.

***4. Why isn't promoting health and wealth directly more effective policy than international schemes to limit emissions and create a complex trading system?***

A recent paper by Tol, Ebi, and Yohe addresses this question. We studied the effects of development and climate change on infectious diseases in Sub-Saharan Africa. We used scenarios of per capita income, literacy, and absolute poverty and of climate change to project the future incidence of malaria. Malaria deaths are projected to first increase, because of population growth and climate change, then decrease because of development. Climate change is important in the medium term burden of malaria. Similar patterns are projected for diarrhea, schistosomiasis, and dengue fever. Climate change is important in the medium term burden of malaria.

The results suggest that development could reduce the burden of infectious disease over the long-term. Progress is projected to be slow, however, with climate change impacts increasing disease burdens over the next few decades. Augmenting current and future interventions specifically aimed at reducing the health burden of infectious diseases due to climate change could save a substantial number of lives in the short-term. Assumptions about economic development in the underlying scenarios led to the conclusion that a policy that only focuses on development, assuming that improved health care would follow automatically, is not advisable.

Reference: Tol RSJ, Ebi KL, Yohe GW. Infectious disease, development, and climate change: a scenario analysis. Environment and Development Economics 2007;12:687-706.

Responses from Dr. Frank Ackerman to questions from the Subcommittee on Energy and Environment, April 7, 2009

Questions from Representative Gene Green:

*1. In order to evaluate the "cost of inaction" on climate change, you compare the economic consequences of two possible climate scenarios: a "business-as-usual" case, or unchecked growth in greenhouse gas emissions, with a "rapid stabilization" case, whereby the U.S. reduces its emissions by 80% accompanied by a 50% reduction in total world emissions.*

> *a. Under your "rapid stabilization" case, what happens if only the U.S. acts to reduce its emissions while major emitters – like China and India – do not follow suite [sic]? Will the costs of inaction become smaller or greater?*

Climate change is a completely global problem; everyone's emissions affect everyone on the planet. My "rapid stabilization" case, like all meaningful scenarios for climate policy, assumes that agreement has been reached about a global schedule for reductions. In the absence of such agreement, we will all face steadily mounting climate damages which will overwhelm our ability to adapt and protect ourselves. That enormous cost of inaction is the reason why global agreement is essential.

On the role of the U.S. in creating that agreement, please see my next answer.

> *b. In your opinion, how critical is it that reductions in U.S. greenhouse gas emissions be linked to global action to reduce carbon emissions? Could we ever achieve a "rapid stabilization" case without strong, mandatory reductions by other major emitters?*

The U.S. and China, the world's top two emitters, each account for roughly 20 percent of global emissions; thus there is no possibility that any country can solve the problem alone. The only important question is: what can each country do to achieve an effective international agreement? Since 2001, the U.S. has been widely viewed by other countries as a major obstacle to such agreement; we were alone among industrial nations in refusing to ratify the Kyoto Protocol, and our government did not offer constructive criticism or proposals for a better alternative. Indeed, some foreign observers started to question why they should take any action when the U.S. was refusing to do so.

The U.S. is the world's largest and richest economy, and one of the top two carbon emitters today (or unquestionably number one, in terms of historical emissions). It is incumbent upon us to take the initiative in proposing bold new global solutions, and challenging others to join us in pursuing those solutions. If we wait for China and India to take the initiative and lead the world on this issue, we will run a serious risk of failing to solve the climate crisis.

Questions from Representative Gene Green, continued:

*2. Your analysis found that under the "business as usual" case, combined increased costs for electricity added up to $141 billion per year by 2100, or .14% of projected U.S. output.*

*Last year, an EPA analysis of climate change legislation (S. 1766, Bingaman-Spector) in the Senate found that electricity prices were projected to increase 40% in 2030 and an additional 25% by 2050. How do these increased costs of addressing climate change in this EPA analysis compare with your estimates under a "business as usual" case for electricity prices?*

It is a mistake to compare increased electricity prices resulting from climate policies to the increased cost of electricity under business as usual. The climate crisis absolutely requires emission reduction; that can be achieved either through market instruments or through government regulation. In order to maximize the role of the market, rather than relying exclusively on regulation, most policy proposals call for raising the price of fossil fuel use, in electricity, transportation and other sectors. That is, the increased price of electricity is an intentional, essential part of a market-friendly climate policy. The only alternatives are much greater reliance on command and control regulation – or failure to solve the climate crisis.

The comparison of increased electricity prices to electricity costs under business as usual is misleading; the emissions from electricity generation affect climate change in general, not just the electricity sector. Climate change is a systemic problem, requiring strong incentives to reduce carbon emissions wherever they occur – definitely including higher prices for fossil fuels.

It is legitimate and important to consider the impacts of energy prices on income distribution. The recent history of generous tax cuts for the wealthy, combined with shredding of the social safety net, have left the U.S. with an extraordinarily unequal distribution of income. Measures to reverse this trend and provide additional resources to those at the bottom of the economic pyramid are desirable in any case – and all the more important when climate policy raises energy prices, which will create a disproportionate burden for lower-income groups. However, policies that compensate lower-income groups should be based on income and needs alone, not on energy costs; payments directly tied to energy costs would undo the benefits of price incentives, forcing more extensive use of command and control regulation for emission reduction.

Questions from Representatives Joe Barton and Fred Upton:

*1. In producing the estimates on climate damages in your testimony, did you estimate how much the cost of adaptation would be and whether that would be cheaper than mitigation? If so, please provide those analyses.*

My testimony did not include calculations of the costs of mitigation; I only provided brief citations to other published cost estimates. I am not aware of any comprehensive estimates of the cost of responding to climate change through adaptation alone; indeed, it is not possible to adapt fully to climate damages, beyond the very early stages of the process. Delays in mitigation, based on a short-run calculation of the costs of adaptation, will only make the long-run problem more severe, and more expensive to solve.

In a co-authored article, forthcoming in *Energy Policy*, I demonstrate that the Stern Review understated the costs of inaction on climate change, in part because it included an exaggerated estimate of the availability of very low-cost adapation. The pre-publication version of the article is available at http://www.sei-us.org/WorkingPapers/WorkingPaperUS08-02.pdf

*2. It's hard not to notice correlations between a nation's economic prosperity and its carbon output.*

There is such a correlation, but it is far from perfect. A closer look at the data shows that there are large differences in carbon emissions among countries at similar economic levels. The same is also true within the U.S.: California and New York have emissions per capita of about half the national average, while Texas, among other states, has emissions far above the average.

> *a. Understanding that there is a relationship, how can we unilaterally decrease our carbon emissions without sacrificing our economy?*

If we forced everyone to live at the economic level of California and New York, where carbon emissions per capita are half the national average, how much sacrifice would be involved? Internationally, Germany has about half the per capita emissions of the U.S.; Germany also has higher average wages than the U.S., longer vacations, better and cheaper medical care, and a large trade surplus. How much sacrifice would be involved in forcing the American people to accept German wages, vacations, and medical care? The point is that a lot can be done by adopting the best practices within the developed world; the U.S. as a whole lags far behind the leaders in reducing the carbon emissions needed to produce a high-income lifestyle.

Questions from Representatives Joe Barton and Fred Upton (cont.):

*b. If we were to decrease carbon emissions without other developing nations such as China and India doing the same, wouldn't we be "unilaterally disarming" our economy?*

We are not facing a threat which carbon emissions can defend us against, so reducing emissions does not represent disarmament. In terms of trade competition, Japan and Germany both have much lower emissions per capita, and have large trade surpluses; in particular, their exports of manufactured goods are much greater than their imports. The U.S. has much higher emissions per capita, and has a trade deficit; we import manufactured goods from many countries, including ones such as Japan and Germany where emissions per capita are lower than ours. It is important for the U.S. to catch up with high-income, relatively low-emission countries such as Japan and Germany, which are succeeding in trade while we are lagging behind.

*c. Wouldn't decreasing our economic output put our national security at risk, and also increase world-wide carbon emissions since China and India are less efficient than the U.S.?*

Emission reduction need not involve a decrease in economic output, as discussed in the preceding answers. One of the greatest threats to global security is the disruption of the environment of developing countries that could result from climate change, and the resulting humanitarian crises, political turmoil, and ensuing waves of migration. Our immigration and border problems could be drastically worsened if climate change drives people out of large parts of Latin America and the Caribbean.

If a reduction in U.S. economic output was replaced by equivalent production in Japan or Germany, worldwide carbon emissions would decrease; if U.S. production was replaced by India or China, worldwide emissions would increase. The inefficiency, or greater carbon intensity, of production in China and India emphasizes the need to transfer new, low-carbon technologies to them (and other developing countries), as part of an effective, long-term solution to the climate crisis.

*3. Here's a sample of problems in the Stern analysis cited by the economists Richard Tol and Gary Yohe:*

Tol and Yohe are not the only economists who have commented on the Stern Review. Their comments were extremely critical, far more so than many economists; their ultra-critical evaluation did not appear well-supported by evidence, in my view. Other opinions that should be noted include:

Questions from Representatives Joe Barton and Fred Upton (cont.):

- Martin Weitzman (Harvard University) said that Stern was "right for the wrong reason"; according to Weitzman, Stern's discount rate was too low, but the risks of catastrophic worst-case outcomes are much more serious than Stern recognized;
- Kenneth Arrow (emeritus, Stanford University), one of the most famous and important economists of the twentieth century, said that the benefits of emission reduction are so great that Stern's proposals would pass a cost-benefit test even at a very high discount rate;
- Terry Barker (Cambridge University) is one of many economists who broadly endorsed the Stern approach.

*a. 50% of the assumed damages occurred after 2200. Can we reliably predict damages two hundred years out? Could we have predicted where we are today in 1808?*

This question raises an important, subtle issue in long-term economic modeling. Any model has to end at some point; but an ongoing physical phenomenon like climate change will not come to an abrupt halt in 50, 100, or 200 years, when our calculations end. The assumptions about damages after the end of the modeling period (200 years, in the Stern Review) are important; the common approach of ignoring this question amounts to implicitly assuming that there will be zero damages after the model ends, which is clearly the wrong answer. Stern, instead, made a plausible assumption about ongoing damages – not a precise, reliable prediction, but a much better guess than damages abruptly falling to zero when a modeling exercise comes to an end. This question matters much more in an analysis with a low discount rate; indeed, the fraction of damages (in present value terms) that occur after 2200 is much greater at a low discount rate, such as Stern used. On the arguments for a low discount rate, see the thorough summary in Chapter 2 of the Stern Review.

*b. The Stern report assumes there is no learning about the climate system as the future unfolds. Is this a realistic assumption?*

I do not believe that this is an accurate description of the Stern Review's analysis. All models assume learning in the form of new, productivity-enhancing, emission-reducing innovation; many models, definitely including the Stern Review's PAGE2002 model, assume significant adaptation to climate damages.

*c. The Stern report overestimates the impact of climate change by cherrypicking; do you have a perspective on that?*

I assume that this question means Tol and Yohe believe that Stern has selectively presented evidence that makes climate change look more ominous than it really is, while omitting evidence that makes it look more benign. If that is the correct interpretation of the question, I completely disagree. Useful references on this point include:

Questions from Representatives Joe Barton and Fred Upton (cont.):

- The Stern Review team's detailed response to their early critics, including Tol and Yohe: Dietz, S., C. Hope, N. Stern and D. Zenghelis (2007). "Reflections on the Stern Review (1): a robust case for strong action to reduce the risks of climate change." *World Economics* 8(1): 121-168.
- Martin Weitzman's influential argument that most economic analyses, including the Stern Review, have underestimated the magnitude and importance of catastrophic worst-case climate risks: Weitzman, M. (2009). "On modeling and interpreting the economics of catastrophic climate change." *Review of Economics and Statistics* 91(1): 1-19.
- My own research group's analysis, mentioned above, showing that Stern underestimated (non-catastrophic) climate damages expected in the U.S. and elsewhere: Ackerman, F., and E. Stanton, C. Hope, and S. Albert (2009). "Did the Stern Review underestimate U.S. and global climate damages?" Forthcoming in *Energy Policy*; see http://www.sei-us.org/WorkingPapers/WorkingPaperUS08-02.pdf .
- Conversely, for evidence that Tol and his coauthors have misrepresented the data in a way that trivializes the climate threat, erroneously making an extravagant claim that the early stages of global warming will save 800,000 lives per year, see Ackerman, F., and E. Stanton (2008). "A comment on 'Economy-wide estimates of the implications of climate change: Human health.' " *Ecological Economics* 66: 8-13.

# Congress of the United States

## House of Representatives

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March 24, 2009

Dr. Patrick J. Michaels
Cato Institute
1000 Massachusetts Ave NW
Washington, DC 20001

Dear Dr. Michaels:

Thank you for appearing before the Subcommittee on Energy and Environment on February 12, 2009, at the hearing entitled "The Climate Crisis: National Security, Public Health, and Economic Threats".

Pursuant to the Committee's Rules, attached are written questions for the record directed to you from certain Members of the Committee. In preparing your answers, please address your response to the Member who submitted the questions and include the text of the question with your response, using separate pages for responses to each Member.

Please provide your responses by April 7, 2009, to Earley Green, Chief Clerk, in Room 2125 of the Rayburn House Office Building and via e-mail to Earley.Green@mail.house.gov. Please contact Earley Green or Jennifer Berenholz at (202) 225-2927 if you have any questions.

Sincerely,

Henry A. Waxman
Chairman

Attachment

**The Honorable Jay Inslee**

1. **Time Series Data Assumption**

   You assume in Figure 4 of your testimony that the temperature in the coming year (2009) will be the same as 2008. Please further explain your justification for making this assumption and whether it is standard scientific practice to assume the value of a single data point in the future when analyzing time series data.

2. **IPCC Climate Models**

   You suggest in your testimony that "rates of warming, on multiple time scales, have now invalidated the midrange suite of IPCC climate models." However, the IPCC Fourth Assessment Report, for which you were a reviewer, concluded: "The ability of coupled climate models to simulate the temperature evolution on each of six continents provides stronger evidence of human influence on the global climate than was available in the TAR." It also contains a figure, TS.23/FAQ 8.1, which shows very good agreement overall between the models and temperature observations over the last 100 years. It further concludes: "There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above....Over several decades of development, models have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases." Please explain your testimony in the context of this document which represents the work of a large community of scientists from around the globe. Also note if the analysis you presented in your testimony has been published in a peer-reviewed scientific journal.

3. **Sea Ice Models**

   Temperature is only one of the possible outputs by which one could evaluate the results of a climate model. Please explain how you interpret model predictions for sea ice in light of the work by Stroeve et al. 2007 (Geophysical Research Letters), which found that arctic sea ice "is declining faster than projected by the majority of the models." Also discuss recent sea level measurements in light of work by Rahmstorf et al. 2007 (Science) which found that "the data available for the period since 1990 raise concerns that the climate system, in particular sea level, may be responding more quickly to climate change than our current generation of models indicates."

**The Honorable Peter Welch**

1. **Employment History**

In reviewing the materials presented by you to the Committee, it appears that your C.V. does not provide your full employment history. Your employment history may be relevant to the Committee's consideration of the testimony you provided. In order for the Committee to better understand how your employment history might inform the Committee's consideration of your testimony, please provide answers to the following questions:

a. **New Hope Environmental Services, Inc.** -- In the C.V. provided to the Committee, you do not list any affiliation with New Hope Environmental Services, Inc. (NHES). However, in an affidavit filed on July 6, 2007 in Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie, you state you are the sole owner of NHES, "a consultancy whose mission is to publicize findings on climate change and scientific and social perspectives that may not otherwise appear in the popular literature or media." In addition, you state in your affidavit that with the exception of modest speaking fees, New Hope is your "sole source of income beyond a negotiated retirement package from the University of Virginia." The NHES website also states the organization is an "advocacy" consulting firm that prepares materials "targeted to user needs."

Please explain why you did not disclose your role in this advocacy firm to the Committee. Please describe your involvement with NHES, including the date that you first became involved with this firm, the nature of your involvement, and any ways in which your role has changed over time. Please describe each type of service provided by NHES. Please describe whether the firm conducts and publishes scientific research for clients, and if so, what the nature of that research is. If NHES conducts scientific research, please state whether NHES has an ethics and/or conflict of interest policy, and if so, please attach a copy of the policy and include the date on which the policy was adopted. Please specify the number of staff employed by NHES, and list the other research scientists that are involved with New Hope Environmental Services, Inc., along with a brief statement of the credentials of each research scientist. Please provide a description of the technological capacity of the NHES research facility, located at 536 Pantops Center, #402, Charlottesville, VA 22911, and any other NHES facility. Please state whether NHES continues to be your "sole source of income beyond a negotiated retirement package from the University of Virginia" and speaking fees. If this is not the case, please list your other sources of income, and indicate whether they are larger than your income from NHES.

b. **The Heartland Institute** – Although it is not mentioned in the C.V. provided to the Committee, you were a contributing editor to the monthly publication *Environment & Climate News* during the period between August 2000 and April 2002 according to the masthead of the publication. *Environment & Climate News* was published by the Heartland Institute, an organization that advocates against climate change regulation according to its website. In

addition, published reports state that the Heartland Institute received substantial funding from ExxonMobil during the period of time you are listed as an editor. The Heartland Institute also states in its 2008 annual report that the primary audience for its publications "are the nation's 8,300 state and national elected officials and approximately 8,400 local government officials." My understanding is that *Environment & Climate News* was regularly delivered to the offices of Members of Congress during the time you were associated with it.

Please describe your involvement with the Heartland Institute. Please explain why you did not disclose your role with an anti-regulatory organization who considers elected officials to be its primary audience. During what years were you involved with *Environment & Climate News* or other publications, projects or other efforts of the Heartland Institute, and in what capacity? Did you receive compensation for your work with the Heartland Institute?

2. **Funding from Parties with a Financial Interest in Government Inaction on Climate Change Issues.**

The C.V. you provided to the Committee contains a section entitled "Financial Support (Over $10,000)." This section appears to contain the identities of organizations that have provided you with financial support exceeding $10,000 since 1980. This list appears to be incomplete, however, as it omits the names of your funders that have a financial interest in government inaction on climate change issues. This information is important in helping the Committee to understand the appropriate weight it should assign to your testimony. In order to clarify this matter, please answer the following questions:

a. **IREA and Tri-State Generation & Transmission Association, Inc.** – In the *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie* affidavit, you acknowledge receiving $100,000 from the electric cooperative Intermountain Rural Electric Association (IREA). According to their website, IREA opposes government action to address climate change, and in a July 17, 2006 letter, Stanley R. Lewandowski, general manager of IREA, wrote that:

> We here at IREA believe that it is necessary to support the scientific community that is willing to stand up against the alarmists ... We decided to support Dr. Patrick Michaels and his group (New Hope Environmental Services, Inc.) ... Dr. Michaels has been supported by electric cooperatives in the past and also receives support from other financial sources ... In February of this year, IREA alone contributed $100,000 to Dr. Michaels. In addition, we have contacted all of the G & T's in the United States, and as of the writing of this letter, we have obtained additional contributions and pledges for Dr. Michaels group.

In your affidavit, you also acknowledged receiving $50,000 from the Tri-State Generation & Transmission Association, Inc. Please describe your financial relationship with IREA and Tri-State Generation & Transmission Association, Inc. Please list each organization or other energy-related business, cooperative

or organization that provided more than $10,000 in funding to you directly or to NHES, and the nature of the services you provided in return. Please explain why you did not disclose this financial support to the Committee.

b. **Western Fuels Association, Inc. - "State of the Climate"** - Although this is not mentioned in the C.V. you presented to the Committee, it is my understanding that you edited and published a series of brochures entitled, "State of the Climate," during the years of 1997 - 2000, a publication that appears intended to dispute the scientific consensus surrounding anthropogenic global warming. These reports were originally published and funded by the Western Fuels Association, Inc. (WFA), a coal supply co-operative, according to an April 22, 1997 letter from the then-CEO of WFA, Frederick D. Palmer. In later years, the reports state that funding was provided by the Greening Earth Society, an advocacy organization in turn founded and funded by the Western Fuels Association and the National Mining Association according to archived records of the Society's website. Both the WFA and the Greening Earth Society were advocating against greenhouse gas emissions regulation during the time you were editing the reports, according to a December 5, 1997 interview with Palmer on *PBS Newshour* and the archived website of the Greening Earth Society.

   Please describe your involvement with the *State of the Climate* publications. During what years were you involved with the project, and in what capacity? Please identify who funded the publication in each of those years. Please also describe whether you received any additional funding from the WFA, or the Greening Earth Society and the nature of the services provided. If this funding supported any work-product on climate-change issues, please list the title of the work-product, and describe whether the work product was submitted to the funders for review prior to publication.

c. **Funding, Production and Distribution of the World Climate Report** – Although it is not mentioned in the C.V. you provided to the Committee, I also understand that you are the editor of the *World Climate Report*, an online publication of NHES. It is my understanding that the *World Climate Report* was published as a periodical during the 1990s before it became an online publication, and was delivered to the offices of Members of Congress. The *World Climate Report* now describes itself on its website as a "response to the global change reports which gain attention in the literature and popular press" and "the perfect antidote against those who argue for proposed changes to the Rio Climate Treaty, such as the Kyoto Protocol, which are aimed at limiting carbon emissions from the United States."

   Please provide the dates of your involvement in the *World Climate Report* and a description of your role, and the role of NHES, throughout that time. Please also list all entities that have funded the *World Climate Report*.

d. **Any Other Funder with a Financial Interest in the Continued Non-Regulation of Greenhouse Gases** – Please identify any other entity which you or NHES have had a financial relationship in excess of $10,000 that is not

identified in your C.V. For each entity, please describe your financial relationship, including the date and amount of funding you received from that entity, as well as the nature of your services for that entity. Please include any information about whether your financial relationship funded published work-product on climate-change issues. If it did, please list the title of the work-product, and describe whether the work-product was submitted to funders for review prior to publication.

**The Honorable Joe Barton and the Honorable Fred Upton**

1. One of the lead authors of the United Nation's 2007 Intergovernmental Panel on Climate Change report, Kevin Trenberth, stated at the journal Nature's blog:

   "In fact there are no predictions by IPCC at all. And there never have been.... None of the models used by IPCC are initialized to the observed state and none of the climate states in the models correspond even remotely to the current observed climate.... The science is not done because we do not have reliable or regional predictions of climate."

   What is he saying here, in lay language? And what does this say about regional assessments and projections of climate change impacts?

2. At the hearing we heard from Dr. Shrag and Mr. Woolsey about tipping points to unstoppable climate change. From your perspective, how should policymakers approach talk of tipping points, which apparently cannot be quantified or predicted with current understanding of the climate system?

3. We have reports today about the climate impacts in the United States from an increased global average temperature, extending fifty years out. Is it possible to predict regional climate impacts based on global average temperature?

   a. What does the observed evidence suggest?

4. Are the models used in the IPCC and the U.S. CCSP useful for projecting future temperature change and climate effects?

   b. To the extent these are used to assess cost-benefits for global climate change, do they create a useful picture for policymakers?

5. If we reduce emissions to a particular level, can we quantify the impact on climate change – such as frequency of droughts, storms, heat waves – using existing models, based on changing emissions levels?

6. Have recent droughts and other climate metrics been predicted by the climate models?

7. Should we base our climate policy on global average temperature or is there another approach to addressing the risks of climate change?

8. Is it possible to reduce global carbon dioxide concentrations without China and India?

9. What would be the global temperature reductions if the United States and Europe met the Kyoto targets, but the developing world didn't follow suit? What would the global temperature reductions be if the United States reduced its emissions to Zero without reductions from developing countries?

**Response to the Hon. Jay Inslee**

Question 1. I assumed that the anomaly for 2009 would be in the same range as the 2008 anomaly because of the La Nina (cold phase of El Nino) conditions extant at the time of my testimony and NOAA consensus forecasts that the ENSO index would (will) remain slightly negative for calendar year 2009. This is also consistent with Keenlyside et al. (*Nature*, 2008), who projected continued relatively low temperature anomalies in both the North Atlantic and Tropical Pacific for several years after their publication.

Question 2. The IPCC models fits are retrospective and largely driven by a combination of radiative effects from sulfate aerosol and greenhouse gases. As is obvious from the IPCC report, there is a very large uncertainty with the aerosol effect, nearly two watts/meter squared. This makes fitting the observed record rather easy, and has been commented on by several individuals. I find the candor of the *second* IPCC report more accurate, which stated that GCM's tended to predict too much warming unless a sulfate cooling is assumed OR the sensitivity of temperature to carbon dioxide has been overestimated. That sensitivity is very hard to deconvolve from with *a priori* logic, as has been attempted, because the changes that we are inducing today are quite different from those in the prehistoric climate. Rather, my approach is to let the sensitivity speak for itself. After all, we have increased the atmospheric concentration of carbon dioxide by about 38% over preindustrial, and there is additional positive forcing from methane and chloroflurocarbons.

I think it is logical to assume, however, that the functional form of the models is largely correct. As you know, the response of temperature to changes in carbon dioxide is logarithmic, while the change in concentration is (in all but the politically unrealistic B2 scenario) exponential. It is not difficult to see why so many models tend to produce linear or quasi-linear future warmings.

Indeed, this is what I took advantage of in my testimony. It is very obvious that the warming since 1977 is best fit by a straight line. It is also obvious that the central tendency of the A1B models is also a straight line, especially in the near term. Consequently, the overlap between the two, and the fact that both rates are constant indeed allows for a robust test based upon the distribution of model results. I must tell you that I was disappointed that I was not given enough time to answer your rather strong criticism of my analysis, but I also understand the nature of the process. So I hope this clears that up!

My work compared the HadCru3 (East Anglia, Hadley Center, "IPCC") temperature history with the A1B scenarios. It was prepared specifically for my testimony, for which, as I am sure you know, I had a total of four work days for preparation. Fortunately, that record is the one most cited through the history of the IPCC and makes for an apples-to-apples comparison. I would like to look at other scenarios and am doing this in my so-called spare time with an eye towards publication as soon as it is done. My working hypothesis is that the only scenario—oddly enough—that will

accommodate the IPCC temperature history within the timeframes analyzed will be B2. In other words, even though we have A1B concentration changes going on, we are getting a B2 response—further evidence that the sensitivity has been overestimated.

The IPCC temperature record is also the most transparent one—at least as can be gleaned from the background literature. It has been subject to continual upwards revision detailed in my recent book "Climate of Extremes", but it does not seem as unstable as Hansen's GISS record, which really has a lot of unexplained and quirky changes.

Question 3. While you state that "Temperature is only one of the possible outputs by which one could evaluate the results of a climate model", it is the *driving* metric. Everything else follows. So I believe it is best to look at that. With regard to the studies you mention, there is an interesting disconnection. Sea-ice records are only comprehensive back to 1979 with the advent of satellite coverage, and it is clear that there is a statistically significant negative trend in the northern hemisphere and a statistically significant positive one in the southern. The combined effect is that we are currently right around the 1979-2000 average, given by the University of Illinois' *Cryosphere Today*. Given that the record begins right at the end of the coldest period in the arctic record since the early 1920s, the overall stability of the global oceanic cryosphere should be encouraging, not discouraging. We have warmed some .48degC (trended value, IPCC record) and in the global cryosphere have precious little to show for it. This is one major reason why I think it is important to proceed cautiously on this issue, despite some very loud voices arguing otherwise.

**Response to the Hon. Peter Welch**

Thank you for your follow-up questions from the hearing entitled *The Climate Crisis: National Security, Public Helath, and Economic Threats.*

My testimony at the hearing focused on a comparison of the distribution of modeled warming trends from the IPCC's midrange suite of general circulation models versus observed trends of from five to 20 years in length in the HadCru3 (Hadley Center, East Anglia "Climate Research Unit", or "IPCC") temperature history. I concluded, based upon that analysis, that the observed trends are largely lying on or beyond the 95% confidence level of this suite of models, which would normally be grounds for rejection of those models. I advised that climate scientists should work to revise those models for better fit, as calculations of the costs and benefits of various climate policies require acceptable models.

I am sending as a separate file my revised C.V., which reflects 2008 and 2009 publications. This is a standard academic C.V., which I submitted along with my testimony and federal grant disclosure form in accordance with Committee rules. A standard academic C.V. includes all peer-reviewed publications, symposium presentations, books and book chapters, but does not included nonacademic publications like op-ed articles or web postings, which are open-source materials.

As I indicated in my testimony at the hearing, my testimony represented no official position of the Cato Institute or the University of Virginia and was tendered as an individual statement under the tradition of academic freedom. Accordingly, I received no specific compensation from any source for the testimony I provided.

**Response to the Hon. Joe Barton and the Hon. Fred Upton**

Trenberth's first statement that "there are no predictions by IPCC at all" is true. Instead, proponents of IPCC's climate model output confuse "predictions" with "scenarios". The two are quite different. It is painfully obvious to anyone with a cursory knowledge of history that projections of future energy type or use in the 100-year time frame are simply unreliable. To call them "educated" guesses gives far too much credit. As an example, consider how different this world is from 100 years ago. In 1909, who would have honestly anticipated—and had the science to back it up—thernmonuclear explosions, transport of a billion people by aircraft, or a small box in your pocket that can access virtually all the information there is in the world?

Consequently, projections for our societal energy structure some 100 years from today, which are the basis for the IPCC's forecasts of temperature change, are, not to put too fine a word on it, *silly*. Basing our Nations' energy course upon such conjecture, attempting to manipulate it with financial incentives, or subsidizing politically favored technologies of any type with significant resources seems foolhardy.

With regard to climate, given that all change from climate models is driven by change in the energy input, it would seem that any projection for 100 years out must be viewed with suspicion.

Question #2: I continue to be mystified by the "tipping point" notion. As an example, note the dozens of climate model/scenario combinations illustrated on page 763 of the 2007 Working Group I report of the United Nations' Intergovernmental Panel on Climate Change (IPCC). It is very clear from looking at these (I included one scenario/multiple model combination in my testimony) that there are no forecast "tipping points", which would appear as a large discontinuity or discontinuities over time. Consequently, if Dr. Schrag and Mr. Woolsey want to speak of "tipping points", that is fine, but it is not within the model consensus of the IPCC. So, in order to do so with confidence, they must somehow invalidated the entire suite of IPCC models.

This issue has also arisen with regard to the so-called "synthesis report" of the U.S. Climate Change Science Program (CCSP), which has gone through two reviews. I noted the use of the words "tipping point" in bullet-point type material at the beginning of the report (i.e. the only part that is likely to be read by a busy non-expert), but then searched the entire body of the report for "tipping point" in an attempt to find the basis for such an assertion. In fact, in both drafts, the words "tipping point" never appear in the subsequent text.

Unless something has more backing than a mere philosophical hand-waving or editorial assertion, I think it is wise for policymakers to stay away!

Question 3. It is a highly dubious exercise to predict regional climate changes in the United States based upon global averages. However, it is more appropriate to examine what *has* happened in the United States as global temperatures warmed for two periods in the 20th century.

In general, precipitation increased over the 20th century, by about 10%, or roughly three inches over the century. Even using somewhat debatable national temperature histories, the amount of concurrent warming was far to little to largely evaporate this increased precipitation. This means that the surface of the United States is, by and large, wetter than it was 100 years ago. This, in turn, and assuming no other great changes, that the nation is greener than it was and produces more food than it would had there been no change.

Question 4. I believe that the models used by the IPCC and the CCSP are useful inasmuch as they tend to predict constant (rather than exponentially increasing) rates of warming. However, the frequency distribution of the IPCC midrange models, as noted in my testimony, indicates that they are at or beneath the normal confidence limits that science uses as a test of a model or a hypothesis. This almost certainly means that the average warming rate predicted by the midrange emissions models is an overestimation, which in turn defuses much of the alarm that is currently associated with this issue.

The lack of confidence that we must place in these models, given the near-equivalence between their 95% confidence range and the IPCC's Hadley Center temperature record, means that they are nott confident estimators of costs and benefits of climate change versus climate policy. I wish this were not true, but it is.

Question 5. The answer for this follows from Questions 3 and 4, above. The short answer is that these models are not working well enough to provide confident answers about local and regional changes in individual weather elements.

Question 6. If an increase in recent droughts were predicted by climate models projecting recent warming, then the models would be in error, at least for regions of the earth where we have good historical precipitation data (which basically means Europe and North America). In both Europe and North America there is no increasing tendency towards persistent drought. Clearly, the most severe and extended drought period in the instrumental record in North America was in the 1930s. Few if any people would seriously related that drought to increases in atmospheric carbon dioxide, for if that were true, the frequency of severe drought would have to be dramatically increasing in recent decades. It is obvious from the history of the Palmer Drought Severity Index over the United States (data available from the U.S. National Climatic Data Center) that there is simply no trend in this important variable back to when systematic records began some 113 years ago.

Question 7. Our climate policy should be based upon rates of change, particularly in vulnerable environments. However, we really don't have accurate models to measure

this at this point in time. Absent any evidence for dramatic change (i.e. the "tipping point" notion discussed above) it seems prudent to wait for better information rather than to bill a large (and unspecified) amount of expenditures to taxpayers with little or no estimate of what benefits, if any, will accrue.

Indeed, if climate change turns out to be much more severe than is currently indicated (given observed rates of warming that tend to be below modeled values), it would seem prudent to have saved money that can be used for investment and adaptation, rather than having spent that money in a futile attempt to stop or something that couldn't be significantly changed.

Whatever the climatic future holds, it should be clear that a vibrant economy contains more capital for investment by individuals in the energy technologies of their choice, and that these investments will be made in larger amounts if such capital is not taken away before it is needed.

Question 8. It is simply impossible to reduce global carbon dioxide concentrations with or without China and India. If one wants to significantly change the rate of increase (an increase in concentration that will still occur for at least another 50 years), one must include China and India in any schedule of binding targets and timetables for emissions reductions. Further, the limits on their emissions must be as severe as those that are being proposed for the United States—otherwise their emissions (as well as their job growth) will swamp that of the now-industrialized world.

Question 9. If all of the world's nations with Kyoto "obligations" met them, the reduction in planetary warming would be 0.07°C per fifty years. This assumes that the sensitivity of temperature to a doubling of atmospheric carbon dioxide is 2.5°C. This is based upon a calculation published by Tom Wigley of the U.S. National Center for Atmospheric Research in the journal *Geophysical Research Letters* in 1998.

For the second part of this question, I assume you are asking what the effect on global warming is if the United States reduces its emissions to zero while everyone else continues "business as usual". Using the Wigley calculation as a basis, this would result in approximately 0.11°C less warming in 2050, and 0.15°C less in 2100.

Looked at another way, how quickly would a complete and immediate shutdown of all U.S. emissions be "made up" by the rest of the world? The answer is in about 6-8 years.